SANITARY WORK

IN

THE SMALLER TOWNS AND IN VILLAGES.

PART I.

SOME OF THE MORE COMMON FORMS OF NUISANCE, WITH THEIR REMEDIES.

1876.

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§ I.—PIGSTYES.

In some parts of the country almost every house has its pigstye. The pig is looked upon as a kind of bank. It is probable that pig-keeping by workmen is not economical, for the meal and other meat required to fatten the pig takes a deal of money, and it would probably pay the workman better to convert the waste products of victuals into manure than to store them in tubs or tanks about the house to feed the pig with. The chief cause of the nuisance of pig-keeping, however, is that the floor of the uncovered part of the stye is too rough to be kept clean. It would seem as if anything were thought good enough to pave the floor with; boulder stones, brick clinkers, or anything whatever which will prevent the pig

rooting into the earth,—a natural propensity of the pig, derived, perhaps, from his wild ancestors, who got their own living in that way. These rough floors, however, cannot be kept so as not to be a nuisance. Pigs, like most other animals, do not void dung on their own beds if reasonable provision is made for them to go elsewhere. When this is done, the straw bed of the pig in the covered part of the stye is preserved tolerably clean; but if the yard or uncovered part of the stye be roughly pitched in the manner above described it will not go out to this part unless the gross inequalities of the floor be covered over—indeed a heavy pig cannot walk over these rough floors. They are then littered. The litter holds together all the dung and urine, and soon becomes a mass of filth; and yet, in consequence of the roughness of the floor, it must lie there until fresh litter is laid down, however foul it may be. It is this retention of filth in the open yard of a pigstye which makes it a nuisance near a house. As to the manure thus made, it is not worth while to subject the health of persons to injury for the sake of it. The remedy for all this is to pave the floor, so that the filth can be swept away daily into a covered cesspit adjoining the pigstye, and to lay a drain from near the top of the cesspit to take away the over-flowing liquid to the same place—whether that be a sewer or an open piece of land—to which the house drainage is taken. But nothing can be done in this, neither in other sanitary requirements, without an ample supply of wat Another thing which makes a pigstye a nuisance where otherwise it might not be so, is the feeding of pigs

with the offal of slaughter-houses. Butchers usually do a large business on small and confined premises, and make the most of everything to their own advantage by keeping pigs, sometimes in large numbers, to eat up the offal. It would be very much better, in every other respect than the undue advantage of the butcher, to convert the offal into manure. When it is considered that it is only in the immediate neighbourhood of a considerable number of dwelling houses where private slaughter-houses exist, we see that neighbours must necessarily be subject to annoyance where large numbers of pigs are kept on adjoining premises, and especially so when these are fed, or partly fed, on the offal of slaughter-houses. Notwithstanding that it might be a harsh law which would prevent a labourer keeping a pig when he believes it to be profitable to him, providing he keep it clean, there are yet certain situations in which a pig ought not to be kept at all, viz. :—(1.) Adjoining the wall of a dwelling-house under a window; for in such a situation the window cannot be opened without admitting the foul emanations of the pigstye, however well it be kept. (2.) Immediately adjoining a public road or footpath. (3.) Near to a public road or footpath when the stye is at a lower level than it; and the greater the difference of level the greater should be the horizontal distance of the pigstye from it.

It is a frequent question of those who wish to con[illegible]m to sanitary regulations, if only they know what [illegible]se are, at what distance from a dwelling-house they [illegible] keep a pig.

[illegible]is would seem to depend upon the state in which

it is kept. If the floor be such that the filth can be easily removed from it, and if a sufficient supply of water be at hand, we may reasonably expect that the stye will be kept in such a condition as not to be a nuisance, and it may in that case be nearer the house than if no care or trouble be taken about these things. The Medical Officers of Health may at some time agree to recommend a certain minimum distance which should be insisted upon in all cases; but until we know what that is, the best thing we can do is to bury as soon as possible all the solid and liquid filth, so as to prevent the formation of injurious gases, or at least to lessen the quantity; and for this reason the floors of pigstyes should be evenly laid, so that the filth may be swept away daily to the land, in the manner already mentioned.

Asphalt is in some places used for the open yard or fold of a pigstye, made with gravel, sand, and the pitch of gas-tar. In other places cement is used, spread thinly over a brick floor laid upon a bed of concrete, and sometimes upon the concrete itself. Where stone flags are to be had within a reasonable distance they are sometimes used, and they make the best floor; but a good floor may be made with bricks alone if care be taken to select them square and well-burnt, and to bed them solidly on a foundation of concrete.

Besides the pig and the stye, another source of nuisance is the swill-tub, or wash-tank. Into it is thrown both vegetable and animal refuse, which decomposes and gives off foul gases. The [illegible] these is assisted by stirring up the contents when the pig is fed. In so far as this cause

contributes to the result it affords a greater reason for insisting upon its being a long way off the house than is afforded by the consideration we have given to the pigstye itself.

There is a little book on "The Pig," by H. D. Richardson, in which he says, "I cannot too frequently reiterate my observations relative to the paramount necessity of cleanliness and dryness." The floor of the fold, he says, should slope towards one corner, and should be of flagstones or pavement, and there should be a drain from the lowest corner to a tank or small cesspit outside, and adjoining the pigstye. "The interior of the covered shed should be kept constantly littered; and so, indeed, should the courtyard or fold, if the object of the keeper is to convert his straw into manure." (Here the author seems to speak of farmers or others having plenty of straw and wanting manure.) "If not, it should be swept and washed clean, and occasionally sprinkled with fresh sawdust."

"There is no better absorbent, no cleanlier material than this, and it is cheaper than straw, when both have to be purchased, much more portable, easier obtained, carried, or stowed away." The object in having the tank, he says, is a double one, viz., "at once to keep the pig-fold and styes in a clean and dry state, and to preserve the valuable liquid manure which comes from the animals you keep." Again, "There are some who probably inquire whether it would not rather be suffer the moisture to soak into earth or straw, substances, *on the floor* of the enclosure, and clear it all away periodically, than to drain off into a tank. For the information of such

persons, I may observe that by drawing off the liquid you add to the cleanliness of your swine, and therefore to their health and capacity for thriving; and also that the collection of the liquid manure into tanks is less troublesome than the removal of substances saturated with it would be."

The section of the Act which relates to pigstyes is the 91st, defining nuisances, in which a nuisance is "Any premises in such a state as to be either a nuisance or injurious to health," and "any animal so kept as to be either a nuisance or injurious to health," and "any accumulation or deposit which is either a nuisance or injurious to health."

§ II.—SLAUGHTER-HOUSES.

The positions of slaughter-houses in rural sanitary districts are generally such as to cause a nuisance. They are mostly behind the butchers' shops, and these are necessarily in the thickly populated parts of the district, and in these parts the ground is in most cases as thickly built upon, for some considerable distance round the slaughter-house, as it is in many large towns. The position behind the butcher's shop is, however, preferable to one which is open to the street, as some slaughter-houses are, and which are both slaughter-house and shop in one. In the case of a slaughter-house in the back premises of the shop (which, by the bye, is in most cases part of the dwelling-house) the objection due to its position is often doubled by its bad structural condition. This is wholly unnecessary and unwarrantable. In addition to this, notwithstanding that the spaces are so small and confined, the nuisance is often increased by keeping pigs to eat up the offal, which is the system of disposing of it, and no regular means of removal are adopted for disposing of that which the pigs do not eat, which is thrown on to the manure heap, exposed to the sun and atmosphere; whereas if the system were to keep no pigs on the premises, but to remove all the offal to a field where they might be kept, then all the offal would be removed together, as a rule of the business, and the premises would be rid of both offal and pigs. This is the practice

in some individual cases, and it should be enforced where necessary, in all cases, on sanitary grounds.

This being done, nuisance arising from the structural defects of slaughter-houses may be abated by the following means. The first requisite is that a sufficient quantity of water shall be close at hand. Some trials to ascertain the quantity required show that about 140 gallons of water are required on each killing day; it is important, therefore, that it should be "laid on" in pipes, for if it have to be fetched from a distance the necessary quantity will not in general be used.

The next requisite is that the floor shall be evenly paved, for a rough floor cannot be kept clean, and there is probably no spot of ground within the compass of the whole area of the district of a sanitary authority that should be so well cleansed as a slaughter-house floor, for the dirt it is subject to is of a kind which is most offensive. But an evenly paved floor and plenty of water must go together. Without a sufficient quantity of water to wash the dirt off an evenly paved floor the beast slips upon it, and a butcher prefers a rough floor under those circumstances. But a rough floor cannot be kept so as not to be a nuisance, however much water may be at hand. No doubt there is some inconvenience to the slaughterman by reason of a certain slipperiness of a smooth floor with blood upon it, but, weighed against the sanitary benefits of a quick removal of all blood and garbage, this cannot be allowed to be a grievance.

Stone flags make the best floor, but grit-stone in any form answers the requirements. It is sufficiently

hard for durability, for the wear is in this case not great, and it is sufficiently non-absorbent. Flags should be of moderate size. If they are small in area, the great weights that come upon them tend to cause an unevenness of the floor: if they are very large they are liable to be broken, unless they are also proportionately thick. It would seem from experience that the superficial area of any one flag should not exceed one square foot for every half inch of its thickness. A firm foundation is necessary, whatever be the material of the floor, but the smaller the individual pieces composing the floor the stronger ought the foundation to be. A bed of concrete twelve inches in thickness will probably be sufficient for any situation, and if the floor be of good stone flags a bed of concrete eight inches in thickness will be sufficient. The concrete should be made with hydraulic lime, or with cement. The common fat limes are not good for foundations.

The edges of the flags should be squared down to a depth of at least two inches, and great care should be taken to make the joints perfectly close with cement, otherwise the infiltration of blood and filth will be a constant source of nuisance. A level floor is better than one laid sloping towards the drain, for the removal of the filth by means of water depends in this case wholly upon manual labour, and not upon natural drainage; and a level floor is less slippery.

The drain from the slaughter-house should have as much fall as the outlet will admit of, and should be of socket-pipes six inches diameter, closely jointed.

The height of a slaughter-house is required by the bye-laws in some districts to be not less than nine feet

from the floor to the wall-plate of the roof, or, where there is a room over it, not less than eleven feet to the ceiling; and that there shall be means of light and ventilation to the extent of at least twenty square feet; also that the lowest part of any opening in the walls shall be at a height from the ground of not less than six feet; that the cleansing of the floor shall be done within three hours of the time of slaughtering; that the walls shall be thoroughly whitewashed with quicklime four times in a year, viz., in January, April, July, and October; but in other places the bye-laws require that this shall be done twice a year, viz., in March and September, and perhaps this may be as far as bye-laws ought to go, for laws must be absolute, and apply to all cases. And in respect of the area of the openings for ventilation, stated above to be twenty square feet, that would seem to be very desirable, for the great amount of vapours arising from the slaughtering and dressing ought to be allowed to escape into the atmosphere as quickly as possible.

Hides and skins should be removed within two days of the time of killing.

Section 169 of the Act directs that, for the purpose of enabling any urban authority to regulate slaughter-houses, the provisions of the Towns Improvement Clauses Act, 1847, with respect to slaughter-houses, shall be incorporated with this Act.

§ III.—PRIVIES AND CESSPOOLS.

There should be a separate privy to each house. Sometimes we find only one to several houses. When this is so, its proper condition is neglected by all, and when complaints are made the neighbours fall to quarrelling, and there is a difficulty in fixing the blame upon the tenant of any one house. But besides this no feeling of decency can be maintained by any of them. In every privy there should be a child's seat, not more than 10 or 12 in. high, while the proper height for the other seat is 18 or 19 in. When the low seat is not provided children are driven to dirty habits. The door should not be hung so that the bottom of it comes close down upon the floor, but there should be a space of 8 or 10 in. between the floor and the bottom of the door, and there should be a hole in each wall, near the top, for ventilation.

An open privy cesspool is in most cases a nuisance. The addition of small quantities of water to effete organic matter causes fermentation and the liberation of the gases of decomposition; and therefore all such matter should either be washed away with plenty of water, or water should be wholly excluded from it. Either an abundance of water or none at all is alone safe in this case. Therefore the cover or roof should be made so as wholly to exclude rain-water. If the ground be a stiff retentive clay, this may be sufficient; but in most cases the ground is more or less porous,

and then the water sinks into the ground and carries with it in solution the contaminating matter of the cesspool, perhaps to a well. So that, at the best, the case offers but a choice of two evils; either the water is evaporated, carrying into the air the noxious gases (and perhaps the germs of specific diseases), or it contaminates the underground water.

These are sufficient reasons why privy cesspools should be covered, but if water is to be wholly kept out of the cesspit it is necessary that it be prevented from soaking into it through the sides or bottom from the surrounding ground; for the water which falls upon the surface and soaks into the ground is drawn towards the cesspool, and enters it through the sides and bottom unless these are water-tight. When we are about to do a thing—though it may be merely the making of a water-tight cesspit—it is better to do it thoroughly, than to make useless the greater part of our labour by withholding the remainder.

There are several ways of making the sides and bottom of a cesspit water-tight. In the case of a new construction the ground may be got out a foot wider each way than the outside dimensions of the walls and 6 in. deeper than the underside of the floor, and this outer space may be filled with puddled clay. The proceeding is to select some good stiff clay and throw it in, and to cut, cross cut, and tread this into one impervious mass, with the use of a sufficient quantity of water only to reduce it to a uniform consistency. Care should be taken not to use too much water. This bottom puddle having been completed, the floor is to be laid and the walls carried up, first to

half their full height. Then all rubbish is to be cleared away from the top of the puddle outside the walls, and the space filled in between the back of the walls and the sides of the hole with puddled clay, previously prepared. The walls should be stayed across from side to side to prevent bulging while the puddled clay is being trodden in, or rammed in. When the walls have been thus backed up to half their height the remainder of the walling is to be completed, and, after clearing away the rubbish from the top of the puddle, the remainder of the puddle backing is to be completed. The walls should be built with hydraulic lime mortar, or with cement, and if sufficient care be taken to stay the walls across from side to side, and to leave in the struts until the mortar becomes hard (on the face of the wall at least) the walls may be half-brick thick; otherwise they should be one brick thick.

Where good retentive clay cannot easily be procured, gas tar may be had. In most places some fine and non-porous material may be had, such as fine gravel, coarse sand, or the refuse of limestone or other quarries. Ashes or other porous material is good for the purpose. Let the material be dry, and pass it through a screen or riddle of half-inch mesh. It has been found, with quarry rubbish, that about three by measure of this material to one of gas tar makes a substance which can be handled with a trowel like common mortar. Having excavated the hole to the required dimensions, and trimmed the bottom level, spread this composition over the bottom and lay the brick floor upon it. The ground should be

got out an inch or two wider each way than the outside of the walls. Carry up the walls to half their height, and, having cleared away all rubbish from the face of the tar-composition below, fill in the space with the same. Complete the walling, and, again having cleared away all rubbish from the face of the tar-composition, complete the backing, taking care to unite the second with the first portion. It is better to make the tar-composition used in the bottom stiffer, and to add more tar for the backing of the walls.

Old brick cesspools are often larger than is necessary. In these cases the dimensions may be sufficient to allow of a half-brick lining. If so, lay the floor in the manner above described, and carry up a half-brick wall all round at a distance of an inch from the old walls, and fill in the space with the liquid tar composition in the manner described.

There are two ways of covering the cesspit so as to exclude rain-water—closely and openly. The open method is the better. It then takes the form of a roof, raised above the ground on posts at the angles, the sides being open. The roof should project sufficiently far over the sides of the pit to prevent the drifting of rain into it. The whole subject may be reduced to this principle, viz., keep all water out and let air in.

An important principle to be observed in sanitary work is that all effete organic matter should be exposed to the action of earth or of atmospheric air, or of both, as fully and as quickly as possible after it has been thrown off, in order that it may become changed into harmless substances, and, for harm,

virtually destroyed. Unless, then, an absorbent like dry earth or the fine ash of house-fires be daily thrown into a covered cesspit, the cover should be so made that the atmosphere may have the fullest play over its contents. The cover should therefore be raised from the ground, and be, in fact, a roof, the sides being open, as in Figs. 1 and 2, Fig. 3 being a plan

Fig. 1.

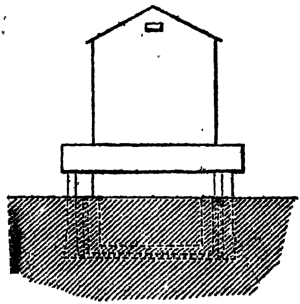


Fig. 2.

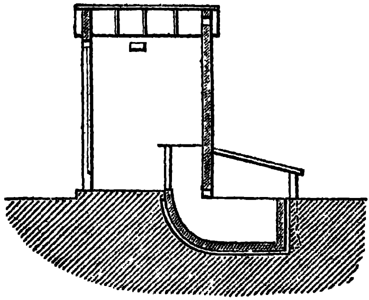
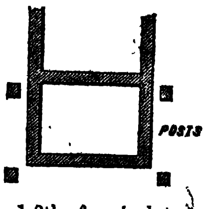


Fig. 3.



Scale—1-8th of an inch to a foot.

of the same. When, however, an absorbent, as one of those above stated, is added daily, the cesspit may be closely covered, as in Figs. 4 and 5. If the cover be of wood, a frame of half battens covered with inch boarding is sufficient, if the joints be grooved and

tongued. Either a part or the whole of the boarded cover should be hinged to the frame, so that it may be opened for the removal of the contents, and so that it may fall down again exactly to its place. Loose covers are seldom put back again properly. In fixing the cover it should be set three inches higher on one side than the opposite one, so that the rain-water may readily run off. The frame should be bedded upon the walls so closely that water cannot soak under it into the cesspit. The cover should be laid with a close joint against the privy wall, the joint being caulked or otherwise made water-tight.

For durability an iron cover is preferable, if it be hinged or have a hinged door, but loose plates are seldom put back again into their proper places after removal for emptying, being too heavy.

The durability of wood may be increased by paying it over with the oil of coal tar pitch. After the naphtha has been removed from coal-tar, the pitch-oil is derived from the residue. Raw coal-tar may be used if one pint of spirits of turpentine be added to a gallon of tar as a drier.

The question arises—What size should the cesspit be? Before determining that, let us consider another important matter connected with water-tight cesspits and with ash-heaps. When the fine ashes and cinders of a house-fire are brought out and thrown into a heap together they are allowed to accumulate because of their worthlessness for any general purpose, and they become a nuisance in several ways. The fine ash is blown about by the wind, and partly into the house again in many cases, and when placed

on or near to a roadside the dust is a nuisance to those who pass. The ash-heap is an inviting place upon which to throw the contents of chamber-pots, and in general it is the common place upon which garbage and the waste of victuals are thrown, where a pig is not kept, and it is thus converted into a foul mass. No one will readily fetch it away, for it is neither clean and useful nor good manure.

Now if, when the ashes of the house fires are brought out daily, the fine ash were screened out of the cinders and thrown into the privy cesspit, that part would be dealt with, and several important advantages would result, for, extraneous water having been prevented from entering the cesspit, the only liquid it would contain would be that of the excrement, and this would be absorbed by the fine ash and kept for manure. The fresh privy excrement would be covered daily with the fine ash. All garbage and waste of victuals should also be thrown into the cesspit and go to make manure.

An open cesspool is economically bad, and wasteful of manure. The contents are reduced to a sloppy mass, which cannot be taken out without buckets, and unless it is carried away without being mixed with ashes or other dry matter on the spot, a barrel is necessary for the purpose; and when it has been thus obtained, at considerable cost of removal, it is hardly worth fetching away, because of the labour of mixing with other substances before it can be applied to the land. When, as is the more general custom, the liquid contents of the cesspool are removed together with the ash-heap, or part of it—that is to say, as much

as the farmer requires for the removal of the liquid contents of the cesspool—the operation is noisome and offensive. But when the ashes are screened the fine ash and the privy soil together form a portable manure, in a state sufficiently solid to be dug out of the cesspit when required. Manure is required for the land chiefly twice a year—spring and autumn—so that in this respect a cesspit should be of a size which will hold the contents for half a year.

The quantity of fine ash resulting from house-fires varies with the quality of the coal. In some districts it averages ¾ cubic foot per week from each fire, and as in small houses one fire only is usually burnt, this becomes ¾ cubic foot per house per week in its dry state, or 20 cubic feet in six months. This 20 cubic feet will absorb 7 cubic feet of liquid, and its bulk will be reduced to three-fourths of its dry bulk, or to 15 cubic feet per house for six months.

I have had in use during the last two years, in the kitchen of the house I occupy at Madeley, one of the ash-screens hereinafter described, which separates the fine ash from the cinders, and I have repeatedly ascertained the quantity of water which a given quantity of the fine dry ash will absorb, and it is as above stated. The spaces between the bars of the grate through which the ash falls are three-sixteenths of an inch wide; a width decided upon, after frequent trials to be the best width.

A depth of 6 or 8 in. of straw, fresh stable litter, sawdust, fern-brake, or other waste vegetable absorbent of that kind, should be put into the bottom of the cesspit before beginning to use it, and each time after

emptying it. Under certain circumstances an excessive quantity of urine is discharged into the cesspit, which percolates into this absorbent material, and is retained at the bottom, and not subject to evaporation.

This will occupy a space of 6 or 8 cubic feet—say 8, making 23 cubic feet. Then the fæces, &c., will occupy a space of 3 or four cubic feet—say 4, making 27 cubic feet, or one cubic yard per house for six months.

But it must be observed that the kind of coal from which the above-named quantity of ash results (which has been found by experiment) is not of average good quality, and probably about ¾ cubic yard per house would be sufficient on the average.

The cinders, being separated from the fine ash, are useful for a variety of purposes. They may be reburnt, or, if not disposed of in that way, they are very useful for roads and footpaths. Nothing makes a better foundation for the metalling of a road than clean cinders, and across wet land nothing makes so firm and dry a footpath; they bind well together, are porous, dry, and therefore clean, which is really a great thing to be desired in rural districts. The slight objection to the dark colour is soon gone after experience of the comfort of walking on such a footpath in wet weather, when perhaps others are almost impassable. But it is only by taking out the fine ash that the house ashes are made thus useful. If at first careless people should spoil their heaps of cinders by throwing on to them such garbage as they ought to throw into the privy cesspits, that will be rectified by a gradual acquisition of common sanitary knowledge; and if this fail, the inspector of nuisances may with more justice

deal summarily with such persons than when no provisions are made to enable the tenants to avoid committing nuisances; for really at present the commission of nuisances is in many cases unavoidable for want of proper structural conveniences on the premises of houses.

An extensive acquaintance with the poorest people shows that there is no reason to doubt the willingness of most of them to keep their houses and premises in a cleanly condition, and to observe sanitary instructions, even though they may entail some extra trouble, provided that practical help is given to them to enable them to comply with those sanitary requirements, and not, as it were, stand a long way off and call out to them to do this or that without making it possible for them to do it. It is in such cases as this that we hear people say, "Oh, they won't take the trouble to keep the place clean, do what you will for them." But that is not true, in any large sense, although it may be so under certain circumstances, as those, namely, where owners of houses never go near their tenants, but leave the collection of rents to agents. These common subjects of pigstyes, privies, cesspools, and ash-heaps, claim serious attention, for a Public Health Act cannot be properly carried out unless the work be begun at the right end, and that we may take to be to get people, each for himself and herself, to perform those common every-day functions of cleanliness which, when neglected, cause an accumulation of evils almost irremovable. It is by dealing with these evils in detail, upon some general and well-defined system, that they will come by-and-by to be wholly removed.

As to the means by which the fine ash may be separated from the cinders, in a simple manner and inexpensively, there is a choice of two or three. 1. A fixed screen, as shown at A, in Figs. 4 and 5, built into the wall of the privy. Figs. 6, 7, 8, and 9 are respectively a section, an end view, a plan, and a cross section of the ash screen, to a scale of 1 in. to a ft. Here the ashes of the house-fires are brought out and thrown into the screen, and with a small rake the fine ash is soon separated from the cinders, and falls down upon the cover of the cesspit, and is pushed through a hole in the wall of the privy, underneath the screen, into the cesspit; the cinders are then raked out of the screen into the box in which the whole had been brought out, and carried back to the fire, or otherwise disposed of.

Fig. 4.

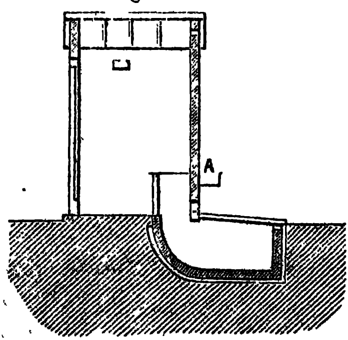
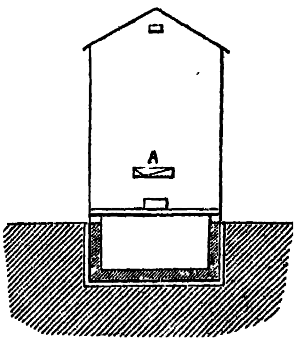


Fig. 5.



The cost of this screen, in the form in which I have had it made, is 6s., and in building a new privy it adds no more than that to the expense; but in fixing it to an existing privy wall, the expense of cutting the

hole and fixing the screen is 1*s*. 6*d*. more, making 7*s*. 6*d*., fixed complete. It weighs 14 lbs.

A fixed screen ot this kind has the disadvantage that the fine ash is blown about during the process of carrying and screening, and to avoid that I have devised a hearth-box, which takes the place of the common grid and hole under the fire-grate. A small

ASH SCREEN.

Fig 6.

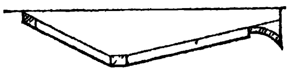


Fig. 7.

Fig. 8.

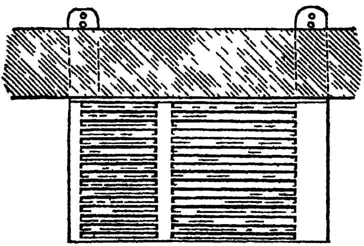
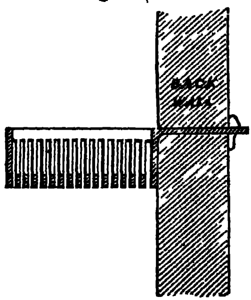


Fig. 9.



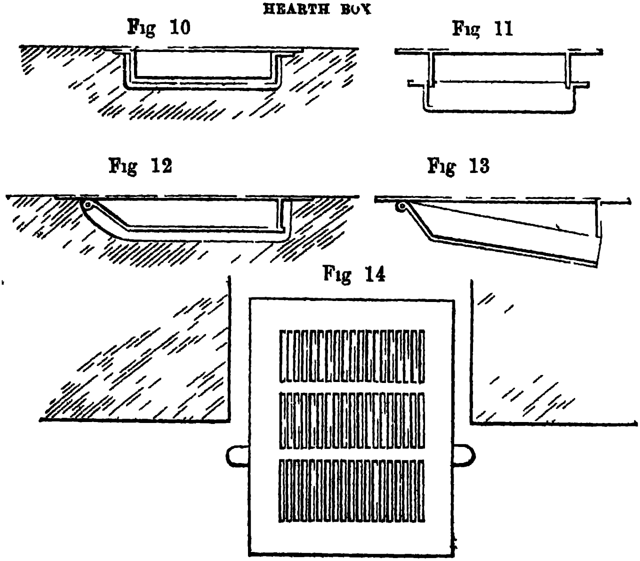
Scale—1 inch to a foot.

box or shallow tray of sheet iron is placed under the fire-grate, having a grid or grating attached to the top of it, which, when in its place, is flush with the hearth-stone. The fine ash mostly falls of itself through the grating into the box. Whenever the hearthstone is swept up the remainder falls through, and the cinders are at once put upon the fire. This is done as often

in a day as a cleanly woman pleases to tidy up her hearthstone.

The size is made sufficient to contain one day's fine ash, so that it must be removed daily. The hearth-box, or cinder saver, as it may be called, being taken to the privy, the fine ash is discharged into the cess-

HEARTH BOX



Scale—1 inch to a foot

pit, either through the privy seat or through a hole in the wall of the privy outside. In this way the excrement is covered daily, while at the same time the fine ash is got rid of, and which is useless for almost any other purpose, and it absorbs the liquids of the excrement,

and converts the whole contents of the cesspit into portable manure, of some value, and which will on that account be the more regularly and frequently removed.

This box is shown in Figs. 10, 11, 12, 13, and 14, and costs about 5*s.*

Cutting the hole for it under the fire-grate costs about the same as cutting a hole in the wall of the privy for the fixed screen, so that (when the ash is discharged from the box through the privy seat) the whole expense is about 6*s.* 6*d.*, and when it is preferred to cut a hole in the privy wall instead of that, the whole cost is about 7*s.* 6*d.*

Fig. 10 shows a cross section of the box, shut; Fig. 11, the front end when open for the discharge of the ash; Fig. 12 a section lengthwise, shut, and Fig. 13 open; Fig. 14 being a plan.

The hearth-box is made of sheet-iron of the thi[illegible] ness of No. 16 wire-gauge. The bars are $\frac{1}{4}$ in., [illegible] the spaces $\frac{3}{16}$ in. When in its place the to[illegible] the grating which covers the box is flush with [illegible] hearthstone, and offers no obstruction to the us[illegible] the brush or shovel. A hole is sunk in the hea[illegible] stone a little deeper than the box, and a chisel-dra[illegible] run round the edges, to receive the flange of the [illegible] The box itself is hinged to the near end of the g[illegible] plate, and has side flanges not quite so wide a[illegible] come flush with the edges of the grating plate, so [illegible] the grating plate can be retained by the fingers' en[illegible] when the flange of the box underneath is let drop for the purpose of shooting out the fine ash through [illegible] far end. The near end of the box is made sloping, so

that it may be more readily picked up from the hearth than if it had to be lifted vertically to the height of its own depth. On each side of the box a half-round chase is cut in the hearthstone, 1 in. wide and ½ in. deep, into which the tips of two fingers of each hand are inserted to pick up the box.

When it is said that six months seems to be the most suitable length of time upon which to calculate the capacity of a cesspit, that is on grounds of utility alone, seeing that it is twice a year when farmers require the manure, and therefore will readily fetch it if it is worth something, and so we might reckon upon getting the cesspits regularly emptied, at least as often as that, if we can convert the privy excrement into a portable manure. But it is, of course, a question on general grounds of health whether privy excrement should be allowed to remain on the premises of a dwelling house so long as that. Unless it be at least once a day covered with ash or dry earth, that would seem to be too long a time; but it is by the Medical Officers that this question must be settled, and the general testimony seems to show that in towns the excrement should either be removed at once, by means of water-closets, or if privies continue to be used in towns, as often as once a week; and this requirement reduces the size of the receptacle to one which can be easily removed, and a tub or pail is then adopted instead of a cesspit. But an important general question must be determined before it can be said which of these two methods—a cesspit or a pail—is to be preferred in any place, rural or urban. It is whether the Sanitary Authority shall undertake the removal of the

privy excrement, or whether it shall be done by individuals, for it is only when the work is done by the Sanitary Authority, under an organised system of removal, renewal, and disposal, that the pail or tub system can be made to work properly.

In devising means to an end it often happens that the object assumes a form different from that first conceived, although it may remain the same in principle: the one form growing out of the considerations given to the other. Thus, as soon as reason has established the case that there should be no open cesspools, but that they should be converted into water-tight cesspits, a little further consideration shows that, when everything is water-tight and dry, no pit at all is necessary. In considering how to prevent exhalations from an open cesspool, the first thing that occurs to one is to cover it; the next to supplement the close cover with water-tight walls and bottom; and, in order to absorb the liquid and hold it for manure, and to deodorise the contents of the cesspit, to throw into it dry earth or the fine ash of the house-fires. But when the contents of the cesspit are thus converted from a liquid to a dry mass, there appears no reason for a pit at all, and no reason why the dry mass should not be deposited on the level of the ground, so as to be easily filled into a barrow or cart in the usual way, and so avoid the useless labour of digging it out of a pit.

All that is necessary in order to make a pit unnecessary is that the floor of the privy shall be considerably higher than the level of the ground at the place where the manure is to be shovelled up into the barrow or cart, and 2 ft. would seem to be a sufficient height

for this. Privies are sometimes built on sloping ground, which gives of itself a sufficient difference of level between the front and back of the privy, or nearly so; but on level ground one of two things is necessary to be done in order to do away with a pit: either to raise the floor 2 feet or so above the ground level and make an inclined walk up to it, or to make steps, say three of 8 in. each.

At the back there should be a projection from the wall of the privy, as shown in Figs. 15 and 16, so as

Fig. 15.

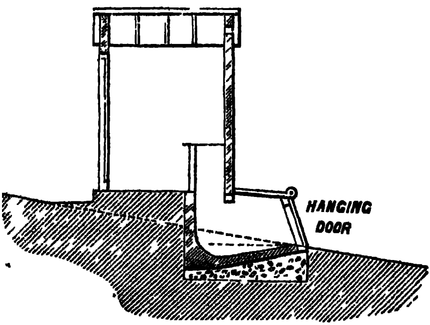
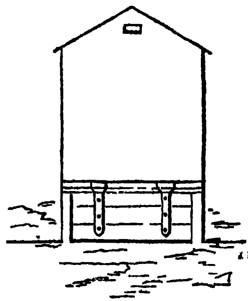


Fig. 16.



Scale—1-8th ot an inch to a foot.

to contain the same quantity as a pit should do in the same place, say ¾ cubic yard for each house, and the floor should be made to slope downwards about 1 in 6, as shown. A hanging door covers the hole through which the place is emptied. The contents being in a dry state, nothing exudes through the opening.

Besides the greater facility of emptying, this plan has the advantage of being rather less expensive than the pit, and especially so on sloping ground.

There is another method which consists in laying a concrete or other floor at the ground level, to receive the deposit, and round the edges of which on three sides the house ashes are arranged. The floor of the privy in this case is raised above the level of the ground—say 2 feet. The excrement and the ashes are mixed together when required to be removed. If the ashes are carefully disposed round the edges of the floor they absorb the excess of liquid and prevent it spreading over the surface of the ground outside. This method, however, would seem to me to be objectionable, unless the floor and the space occupied by the ashes were roofed over. That being done it would be preferable to a pit. Indeed any kind of pit is to be avoided if possible. The open pit ought not to be allowed under any circumstances, and, seeing the difficuity of making a pit water-tight, it is advisable to have none at all. But the roofing over is absolutely necessary.

By section 35 of the Act every new house is to have a sufficient water-closet, earth-closet, or privy, and an ashpit furnished with proper doors and coverings; and by section 36 *any* house without a sufficient water-closet, earth-closet, or privy, and an ashpit furnished with proper doors and coverings, is to be provided with these within a reasonable time to be specified in a notice to be given to the owner or occupier. If the notice is not complied with the local authority may, at the expiration of the time specified in the notice, do the work thereby required to be done, and may recover the expenses from the owner: or may declare the same to be private improvement expenses; provided

that where the convenience has been and is used in common by the inmates of two or more houses, or if in the opinion of the local authority the convenience may be used by the inmates of more than one house, they need not require one to be provided for each house.

§ IV.—BAD AIR IN HOUSES.

Those persons who go much into small houses, whether in town or country, find a fetid odour and a close and stuffy condition of atmosphere prevalent in all parts of the house. This fetid odour is distinct from that of sewers and drains, and prevails also where there are none of these. It is the exhalations from animal bodies, human, canine, feline, and other, and from dirty clothes brought into the house damp, and there left to dry; from dirty bed clothes, which have absorbed the perspiration of persons during the night, and give it off in vapour during the day; and the general dust of the house.

When we consider the chemical composition of atmospheric air in different places, it is surprising how small the difference is—in figures. Atmospheric air consists, in the main, of two gases, viz., nitrogen and oxygen (the nitrogen being inert and the oxygen the life-sustaining portion), with a small quantity of a third, viz., carbonic acid. Dr. Angus Smith has recorded, in his book on "Air and Rain," that the usual amount of oxygen in the atmosphere—that is, the average analysis of the air of all places, good and bad—is 20·96 per cent., or 209·6 cubic feet in 1000 cubic feet of air. The air of the seashore and the open heath, he says, contains 20·999 per cent. of oxygen. In a room which felt close, but not excessively so, the amount was found to be 20·89 per cent. In a

very small room, with a petroleum lamp burning and a good deal of draught, the quantity of oxygen was 20·84 per cent., and after the lamp had been burning for six hours it was 20·83 per cent. At the backs of houses in Manchester it is 20·70 per cent. In a crowded law court in London an analysis gave 20·65 per cent. When a candle goes out it is 18·50 per cent. The worst specimen examined from a mine was 18·27 per cent.

No air in nature contains more than 21 per cent. of oxygen, and none contains much less. It is proved, Dr. Smith says, that badly ventilated rooms containing less than 20·7 per cent. of oxygen are very unwholesome.

"Some people will probably inquire," he says, "why we should give so much attention to such minute quantities, thinking these small differences can in no way affect us. A little more or less oxygen might not affect us, but supposing its place occupied by hurtful matter we must not look upon the amount as too small. The difference between 20·999 and 20·980 is 190 in a million. In a gallon of water there are 70,000 grains. Let us put into it an impurity at the rate of 190 in 1,000,000; it amounts to 13·3 grains in a gallon. This amount would be considered enormous if it consisted of putrifying matter, or any organic matter usually found in water. But we drink only a comparatively small quantity of water, and the whole 13 grains would not be swallowed in a day, whereas we take into our lungs from 1000 to 2000 gallons of air daily.

"The detection of impurities in the air is therefore of

the utmost importance. We must remember also that the blood receives the air and such impurities as are not filtered out in its passage, whilst it is the stomach which receives the water we drink, and that organ has for many substances a power of disinfection and destruction which the blood does not possess."

The quantity of carbonic acid in the atmosphere is stated by the same authority to be as follows, at Manchester:—

In the streets in usual weather, ·0403 per cent.; during fogs, ·0679; about middens, ·0774; average of all the town specimens, ·0442; where the fields begin, ·0369; minimum of suburbs, ·0291; and in close buildings, ·1604 per cent.

In the London parks and open places the per-centage of volume is ·0301; in the streets, ·0380.

On hills in Scotland, ·0332 the lowest, and ·0341 the highest per-centage.

Dr. Bernays found in a Chancery Court, with closed doors, at a height of 7 ft. from the floor, ·193 per cent, at a height of 3 ft. from the floor ·203 per cent. of carbonic acid gas. The worst specimen from a London theatre, at eleven o'clock at night, was ·320 per cent.

Dr. George Wilson, in his "Handbook of Hygiene," says, "the question resolves itself into this—What amount of carbonic acid shall be accepted as the standard of permissible maximum impurity? After numerous experiments and a most extended inquiry, Dr. Parkes has given it as his opinion that, allowing ·4 volume as the average amount of carbonic acid in 1000 volumes of air, this standard ought not to

exceed ·6 per 1000 volumes, because, when this ratio is exceeded, the organic impurities, as a rule, become perceptible to the senses. With a ratio of ·8, ·9, or 1 per 1000 volumes, the air smells stuffy and close, and beyond this it becomes foul and offensive." Dr. Wilson corroborates these remarks of Dr. Parkes from his experience of prisons, a class of buildings which afford opportunities of arriving at an approximate and practical solution of this problem.

Dr. Angus Smith, in "Air and Rain," says, "we all avoid an atmosphere containing ·1 per cent of carbonic acid in crowded rooms; and the experience of civilised man is that it is not only odious but unwholesome. When people speak of good ventilation they mean, without knowing it, air with less than ·07 per cent, of carbonic acid."

Dr. Parkes gives the average amount of carbonic acid exhaled by an adult in the twenty-four hours as 16 cubic feet, or a little over ·6 cubic feet per hour.

Dr. Wilson points out that when lights are used, and the products of combustion are allowed to pass into a room, the supply of fresh air must be augmented in order to maintain the standard of purity.

"It is found that 1 cubic foot of coal gas destroys the oxygen of 8 cubic feet of air in combustion, and produces about 2 cubic feet of carbonic acid, besides other impurities. As a common gas burner burns about 3 cubic feet of gas per hour, the importance of having these deleterious products of combustion carried off by special channels will be readily admitted."

Taking ·6 carbonic acid per 1000 volumes of air as

the standard of maximum impurity, and ·6 cubic feet of carbonic acid exhaled per hour, and taking the initial carbonic acid contained in the atmosphere at the normal ratio of ·4 per 1000 volumes, Dr. Wilson says, "the quantity of fresh air which should be supplied is found by calculation to amount to 3000 cubic feet per head per hour, in all cases where the diffusion of the contained air is uniform." If, instead of ·6, a lower standard of ·7, ·8, or ·9 volume of carbonic acid per 1000 volumes of air be fixed upon, the amount of fresh air required would be proportionately less, of course;—would be 2,000, 1,500, or 1,200 cubic feet per head per hour. Actual experiments made at five o'clock in the morning at Aldershott Camp show that in a room with a supply of 1,200 cubic feet of fresh air per head per hour the carbonic acid was ·855 per 1,000 volumes; in another room with a supply of 1,700 cubic feet it was ·759 per 1,000 volumes; and in a third room with a supply of about 765 cubic feet per head per hour it amounted to 1·2 per 1,000 volumes.

The foregoing calculations and facts show the quantity of fresh air required to be admitted into rooms in order to prevent the quantity of carbonic acid gas increasing beyond a given standard; but as soon as we come to apply the rule in practice the question of the capacity of the room comes in, with its many difficulties, and also the means of admitting the fresh air, for although we might cause the required quantity of fresh air to pass through the room, yet its velocity through small spaces would probably produce such draughts as would be intolerable. We find it to

be so in practice. When the only means of admitting fresh air is through the doors and windows, a person in a small room is exposed to draughts of air in almost any possible position, and we commonly find holes in walls stopped up to prevent these draughts—and not merely to keep the house warmer. It is the same whether the hole be under a door, a broken window-pane, or whether it be a purposely-fixed ventilator; people will not leave them open. They would be glad enough to have fresh air if they could have it without draughts; and I have known holes knocked through the back walls of houses by the tenants themselves, but stopped up again because of draught. To make the air of dwelling-houses fit to live in is one of the most important objects of a sanitary authority. Persons who are tolerably wealthy may accomplish this for themselves, but it is the necessities of the multitude that engage the attention of a sanitary authority. The ventilation of houses is as difficult as ever the sewage question was, and will require for its solution as much research as has been given to that question, and which must be accomplished by legislation as efficient as that now in force and that which may follow on the sewage difficulty.

Bad air is aerial sewage, and must be cleansed by oxidation before we can safely breathe it, as foul water must be before we can drink it.

The sections of the Act which relate to this subject are the 91st, which declares "any premises in such a state as to be either a nuisance or injurious to health" to be a nuisance, and the 46th, which is as follows:—

Where, on the certificate of the Medical Officer of

Health, or of any two medical practitioners, it appears to any local authority that any house, or part thereof, is in such a filthy or unwholesome condition that the health of any person is affected or endangered thereby, or that the whitewashing, cleansing, or purifying of any house, or part thereof, would tend to prevent or check infectious disease, the local authority shall give notice in writing to the owner or occupier of such house, or part thereof, to whitewash, cleanse, or purify the same, as the case may require."

§ V.—DIRTY HOUSES.

We do not find clean people in dirty houses, nor dirty people in clean houses. When we look into the causes of dirty houses we find that want of proper drainage for the house slops is one of the chief of them. A house must be considered to extend beyond the threshold of the door for at least some yards. Where, for some yards in front of the house-door, the surface of the ground is not paved, or so roughly paved that liquids cannot run off cleanly from it—that is one cause of a dirty house. The children run in and out many times in a day; and every person and animal of the household brings dirt into it continually. The poor woman may try to rectify all this by scolding the children and kicking the dog, or may drive the children away altogether, for some hours at least, to find a better place to run about in; but it all ends in failure and bad temper, and the house becomes permanently dirty. The dirt on the floor dries, and is kicked or blown about in dust, which settles on the furniture and clothing, the walls and the ceiling, and is even carried upstairs. Bed-clothes are thrown on to the floor for want of other convenient place; washing day would come very often if it were to come often enough to keep things clean; and often withal there is a want of water. But the strength of spirit and of body required to keep a clean house under these long-continued adverse circumstances dies out,

and the house falls gradually into a chronic state of dirt. The husband becomes dissatisfied with it, and with all in it, and the usual consequence of that is too well known to need to be mentioned; it is enough to say that it is one of the circumstances of his life which does not tend to maintain his health.

Less money than the wife wants comes into the house because the rest has gone elsewhere. Children's clothes become worn out until scarcely any remain. She starves herself to feed her children, and even then insufficiently for their health. Sickness comes into the house, with its consequent expenses. A dirty household is under these circumstances kept together as long as possible, but a frequent consequence is the necessity of parish relief, and the owners of house-property pay perhaps more money in unnecessary poor-rates than would be necessary for all the expenses of drainage.

Dirty roads are another cause of dirty houses, and are uneconomical as well in the cost of maintenance.

It is ruinous to a road to allow water to lodge upon it. If the object were to grind down the material by means of wheels and horses' feet we should add water to them, and that is practically what takes place when water lodges on a road. It is a matter of experience, after taking into account all charges of road-maintenance, that the cheapest materials for the road surface are the best in quality. Trap rock is the best material; sandstone is weak; limestone is slippery; flint is too brittle; granite, of certain qualities, is a good material, but trap rock is better; it

has a property of toughness as well as hardness. The pebbles and boulders picked from agricultural land are good for the purpose, when broken and made angular, so that the stones interlock with each other. It is necessary that there should be a good depth of stone—say ten or twelve inches—but it is not necessary that it should all be of the quality which is suitable for the surface; the lower half or two-thirds of the depth may be of inferior quality, such as sandstone, for this part is to be regarded as the foundation only, and is never to be reached by the wheels of vehicles or by horses' feet. It should, however, be broken to the same size as the top stone, or metalling, otherwise it will work up to the surface, and the size should not be larger than would pass through a ring two inches in diameter. Stone of two kinds, differing in hardness, should not be mixed together; the softer wears away before the other, and leaves an uneven road; but if placed altogether below the hard stone it serves the purpose of supporting the better material. Roads come properly within the category of sanitary works. Dust is certainly a nuisance, and mud is no [illegible] both are sources of dirty houses. Even [illegible] monetary point of view, a good hard material [illegible] metalling is economical; less dust and mud [illegible] produced, because there is less wear. It is the wearing away of the materials in wet weather which produces first mud and then dust. The carting of [illegible] quantities of poor material on to a road, and the removal of large quantities of mud from it, cannot be economical. And be it remembered that the removal [illegible] the mud takes place and must take place whether

labourers be employed to scrape and sweep it up, and carts be employed to remove it, or whether it be left to be washed away in heavy rains into the drains, or, in lighter rains, to be ground up and remain to be blown away by the next dry wind. To have it washed into the road drains is to have them choked; then the road-labourers disturb the construction of the drains or culverts and clean out the deposit, and restore the construction in a very rough and inefficient manner, making stoppages all the more likely afterwards. So that the ground-up material is necessarily removed, either as mud or dust. Watering roads, too, is expensive work. The expense of all these is reduced by making the top metalling of roads with better material.

Sir Henry Parnell, in his book on roads, gives the results of experiments on the force required to draw given weights over roads of various degrees of cleanliness, which show that for the same load the following very different degrees of force are required for the draught.

On a muddy gravel road	32
On a clean gravel road	13
On a muddy road which is made with good broken stone .	10
On the same road covered with dust	8
On a well-made broken stone road in a clean dry state . .	5
On a paved road	2

In a paper contributed to the Institution of Civil Engineers by Sir Joseph Whitworth some years ago, on the advantages and economy of maintaining a high degree of cleanliness in roads and streets, it is said that it is a remarkable fact that the quantity of dirt

removed is not increased by frequent cleansing, but is indeed under some circumstances diminished. This can only be explained by the fact that very much less dirt is produced on roadways which are kept properly cleansed, and that therefore they are preserved. This effect of improved cleanliness has been generally observed, and its cause is that when dirt is allowed to remain on the surface of a road it retains the water. A curious illustration of the preservative effect of cleanliness of a roadway is afforded by the state of the crossings, where the roads are "macadamised" or made with broken stone. The sweepers keep their crossings clean by constant sweeping; but the road, instead of being, as might have been expected, worn away at the crossing, is often found higher and less worn than the adjoining parts. The saving of the material is no doubt the consequence of the greater dryness, and therefore hardness, of the clean part of the road. In the discussion on this paper, Mr. P. H. Holland said that one of the best effects of clean streets was that the houses were more easily kept clean, and the effect of this upon the habits and morals of the people was most important. If persons could not keep their houses clean with a reasonable amount of care and trouble, they soon gave up the attempt, and submitted to live in dirt. This domestic dirtiness caused domestic discomfiture, which naturally led the husband to desert his own fireside for the public house. If, however, the streets were kept clean, it became comparatively easy to keep the houses so. He had frequent opportunities of watching the effect of improvements in this respect, and it invariably followed

that there had been a marked improvement in the habits and morals as well as in the health of the people.

The condition of public roads is of great importance in another respect. How shall we call upon persons in their private capacity as householders to keep their houses clean when the public authority make it almost impossible to do so by neglecting the condition of the streets and roads? It is one of the gravest questions which a sanitary authority can entertain, whether they do not themselves contribute to the dirty condition in which we find the houses of poor people. And as to the question: Which are public roads? it ought not to arise, for all roads which are used by the public ought to belong to the public authority. It is of frequent occurrence that roads, originally private ground, are thrown open to the use of the public without having been first properly made by their owners, and when the public authority is asked to take to these roads and keep them in repair they very properly object to do so until they have been put into a proper state of repair by the original owners; but the public having used these roads—in some cases for many years—the original owners say the road is no longer private, and is now public ground. These contentions cause much difficulty, and are injurious to all parties concerned. The course of proceeding should be that when a road not properly made is thrown open to the public by the owner of adjoining property for the convenience of the tenants, the public authority should bar the road to carriage traffic until it shall have been properly made, and then take to it as a

public road. By allowing it to be used by the public before it is properly formed, the public authority create a difficulty for themselves, but by placing a bar across one end, upon the public road with which it communicates, the owner of the private road sees that it is his interest to make the road properly at once. But as a practical remedy for former laches on both sides it seems proper and just that all such roads now existing should be put in order with the assistance of the sanitary authority, and that in future a better system of procedure should be adopted; for, besides the necessities of roadways in such cases, it is frequently a present necessity of the sanitary authority that sewers be laid in such roads.

§ VI.—DAMPNESS OF HOUSES.

It is unnecessary to describe the many evil effects of dampness of the floors upon which, and the walls against which, people lodge. The chief cause of dampness of houses is the want of proper eaves-troughs and spouting to the roofs, and where the precaution has not been taken, in building the house, to lay a damp-proof course, the evil effects are excessive. When there are eaves-troughs at all they are in many cases so narrow that either the rain-water of the slighter showers falls short of them, or that of the heavier showers overleaps them at their lower ends and for some distance upwards. They are in many cases no more than 3 in. in width. They should be 5 in. The edges of the trough should be fixed at the upper end level with the edge of the eaves, and an inch or so within that edge all along the trough, so as to catch the slighter showers which drop sheer down. It is chiefly towards the lower end of the trough where the water runs over the edges, and besides being caused by the trough being too narrow in many cases, another, and a frequent cause, is the want of hopper-heads to the down pipes. We see a small hole cut in the bottom of the eaves-trough, and the down-pipe joined immediately to the trough. The mouth of the pipe is too small to admit the quantity of water due to the

capacity of the pipe itself. The full quantity of water that a pipe of given size is capable of conveying cannot enter it through a mouth of its own diameter merely, and it is necessary to enlarge the mouth of the pipe. This is done in the case of eaves-troughs by a separate wider piece, called a hopper-head. But where there are no eaves troughs at all we may see by a rough calculation how much water is poured down at the foot of a house-wall. If we take each slope of the roof of an average house to be 180 square ft., a rainfall of one-third of an inch in an hour amounts to more than thirty gallons in that time, poured down along the foot of the wall. And it should be noticed that the surface of the ground about house walls in rural districts is usually not so evenly flagged, or otherwise paved, as it is in towns, and therefore that the water does not so quickly run off, but lodges about the foundations to a much greater extent, and is absorbed by the walls and given off inside the house in vapour. This is especially so with stone walls. In hilly districts we sometimes find the surface of the ground at the back of a house several feet above the floor level, and no space left between the wall and the earth. Water falling from the roof in such a case makes the house unfit to live in. Everything put against or near the wall soon becomes mouldy, and it is first dragged further away, but for want of sufficient room it is soon put back again, and the consequence is that rheumatism and other diseases take hold of the inhabitants, and illness and inability to work ensue.

The remedy in a case of this kind is to cut down the earth at the back and leave a clear space of a yard

or so between the wall and the earth. One foot below the floor level is a sufficient depth generally. It is easy to see how such cases have arisen; the retaining wall necessary to be built to keep up the earth has been made use of as the back wall of the house.

§ VII.—STORAGE OF RAIN-WATER FROM HOUSE-ROOFS.

THE rain-water falling upon the roofs of most houses considerable size is caught and stored for use, ıereby avoiding, to some extent, dampness of the ›undations and other inconveniences. It is in the maller houses we find this provision mostly neglected. easurements of the areas of some thousands of ouse-roofs show an average roof area of about 360 quare feet per house. An average rainfall of 30 ıches per annum is not unusual, and if we reduce is to 24 inches we could probably collect most of at in tanks, for upon so steep a surface nearly all ould run off; but allowing 6 inches in depth for vaporation, there would be left 18 inches in depth vailable for storage, which would amount to 540 cubic ›et, or 3375 gallons in the year, which would yield a aily average supply of 9 gallons to the house. If all ıe rain-water is to be stored and used gradually and quably day by day, the capacity of the tank should e from about 1000 gallons in the western counties about 2000 gallons in the eastern counties, but the ıles of storage capacity applicable to water-works eservoirs do not apply in this case, because, in small ouses, it is impossible to limit the quantity daily out of the tank (although that is quite practi- in the case of a mansion), and if the proper erage daily quantity be exceeded it throws out any

calculation which might be made on the basis of a given daily quantity to be used. If the tank be made to hold 1000 gallons, it will be of reasonably sufficient size for one house, and this would be contained in a space 6 ft. square and 4½ ft. deep, or in one 5 ft. square and 6½ ft. deep. But, perhaps, the cheapest tank that can be made is a well. A circular well may be sunk, 5 ft. diameter, to a depth of 15 ft., and if the ground be a stiff retentive clay to that depth, a trial hole should be dug in the bottom to the depth of a foot or 18 inches to ascertain that the clay continues to a sufficient depth below the bottom of the well, the hole being carefully filled in again with puddled clay. The well may then be lined with half-brickwork in hydraulic lime mortar, leaving a clear diameter of 4 ft. 3 in. If the bricks be laid dry the water will pass through the joints to the clay at the back and dissolve it, and part of it will be washed into the well as the water-surface lowers; and if the mortar be made of other than hydraulic lime it will be dissolved. Where the ground is porous this lining could not be depended upon to be sufficiently water-tight. In that case the brick lining should be of radiated bricks, with close vertical joints, and backed with puddled clay, 8 or 9 inches in thickness. Instead of clay a common kind of asphalt may be used, composed of gas tar and any non-porous dry material screened through ⅜ in. meshes, and worked in the manner already described for dry cesspits (see § III.), both floor and backing of walls. The thickness of this need not be more than an inch, but care should be taken that it is not less in any part than ½ an inch. In this case the radiated

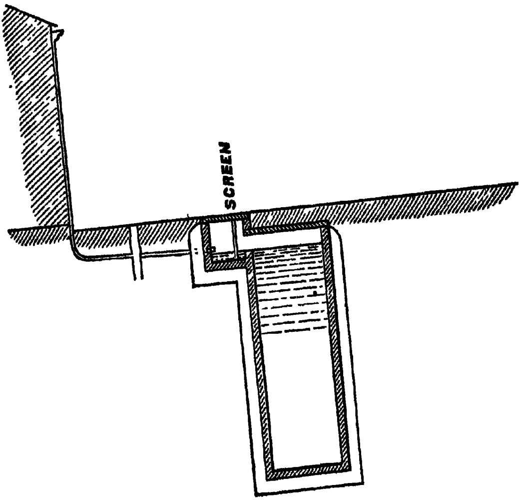
well bricks should also be laid with hydraulic mortar or with cement.

Another method is to use no bricks at all, but to render the sides of the excavation with Portland cement in three coats, the full thickness of the cement being not less than an inch. In this case it is very necessary that the sides be trimmed down to an exact circle. It has been objected to this method that the ground water may rise outside the tank above the level of the water within it, and, by its hydrostatic pressure, burst off the cement lining. This would probably be so if care were not taken to make the excavation circular; but that being done, and there being necessarily an equal external pressure all round the well, the cement ring would be put under a compression not greater, in all probability, than it could withstand. If it be desired to have a brick lining, and to coat the face of that with cement, the bricks should be laid dry, to prevent settlement of mortar joints.

A well of the small diameter above stated may easily be covered with stone flags, or cast-iron plates, or it may be domed over. It is necessary to leave an air-hole in the cover, and to protect it with a hood so that it cannot be reached for mischief.

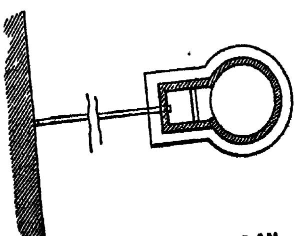
Fig. 17 shows a section and Fig. 18 a plan of a rain-water tank of this kind. The leaves and other things which are brought down by the rain-water from the eaves troughs should be intercepted before they reach the well. This is done by placing a copper wire gauze screen across a small receptacle in which the deposit takes place, and from which it is removed from time to time and the gauze screen washed.

Fig. 17.



SECTION

Fig. 18.



PLAN

The cost of a rain-water tank, made in the first-mentioned manner, will probably be about £7 0 0

In the second	8	0	0
In the third	8	0	0
In the fourth	8	0	0

in each case including the pump and all, complete.

If we suppose the tank and pump to last, with a full allowance for repairs, only 30 years, there would be procured in that time 100,000 gallons of water. If we take the first cost at £6, and allow 2 per cent. per annum for repairs, or 2*s*. 6*d*. every year during the 30 years, and add 3*d*. for redemption in 30 years at 5 per cent., and capitalise that combined annual payment at per cent., we shall add 55*s*. to the £6, making £8 15*s*., or say £9. For this sum, including prospective expenses for 30 years, a quantity of 100,000 and odd gallons of water would be procured, being at the rate about 1*s*. 9*d*. per 1000 gallons, or 48 gallons for a penny.

If the first cost of the tank and pump be £8, and including the same percentage for repairs, &c., there would be procured 36 gallons for a penny. When we consider that when the rain-water is not stored for use in a locality where water is scarce and has to be fetched from long distances, or, if not actually fetched by the inhabitants, paid for at the rate of 4 or 6 gallons for 1*d*., which is not an uncommon thing, the advantage of storing the rain-water of house-roofs is sufficiently apparent.

Except for the expense, it is advantageous to catch the roof-water before it descends to the ground, so that from an elevated tank a pipe may be laid into the

house. This also affords facility for filtering the water. When the ground-water contains certain mineral properties, some persons find it disagree with their health, and are glad to drink filtered rain-water.

The ordinary sand-filter, such as is in use on the large scale, cannot well be adapted to filtration on the small scale of the necessities of one small house. The area of a filter-bed is usually on the scale of about one-third of a square foot per head of the population, but we cannot make a filter for one house on the same scale, unless it be a mansion, or large house. In a general filter-bed the action is continuous, minute by minute, although the water is suddenly drawn from the mains in quantities of several gallons at intervals of an hour or two, taking house by house throughout a district. It is this intermittent action which makes the difference between the two cases. A general filter bed yields about 75 gallons of water in 24 hours per square foot of its area, but for the reasons stated we cannot reckon the size of a sand filter for one ho on that scale. We frequently require to draw four five gallons, or more, in a minute, and to obtain th quantity through a sand filter at the ordinary speed descent would require a much larger area than wo be practicable or convenient.

The purification of water passing through any filter-bed takes place by reason of two separate actions upon it, first by straining out of it the solid matter in suspension, and secondly by bringing the oxygen of the atmosphere to act upon it so as to change any decaying organic matter which it may contain in solution into inorganic and harmless substances. The best filte

medium, therefore, is that which at once excludes from its pores suspended solid particles and exposes the dissolved organic matter to the largest possible amount of atmospheric air. Fine sand, by reason of its heaviness, lies too compactly in its body to comply with the latter requirement, while in its surface it is too porous to exclude all suspended matter. On the large scale this is of no practical inconvenience, because, although the solid matter may not be altogether arrested on the surface, but may penetrate the sand to the depth of an inch or two, it is easily removed by a regular attention, but the case of a small household filter is quite different; here no such regular attention is given, or could practically be given, to remove the solid material and replace it from time to time with fresh material. Some substance, therefore, must be used which is closer in its texture on the surface and more open in its body than a sand-bed is. Charcoal is a very porous substance, but the difficulty is to make the water pass through the pores; for when the charcoal is in the form of lumps, however small, the water passes through amongst the interstices of the lumps or granules, and not through their pores, thus coating the surface of each lump or granule with the impurities of the water, and for a time, therefore, depriving the water of them, but afterwards allowing it to pass through unpurified, and even, after further use, giving off to it part of the accumulated impurities of the water which had previously passed through. This was found to be the result of passing water through a thickness of five inches of animal charcoal of a degree of fineness similar to that used in sugar refineries,

according to a paper read at the Institution of Civil Engineers, in 1867, by Mr. Edward Byrne. The experiments Mr. Byrne made were not considered conclusive of the case, for there seemed to have been some peculiar property in the water; but, however that may have been, the experiments certainly did show that, after a certain quantity of water had passed through the filter, the remainder was in worse condition after than before it passed through.

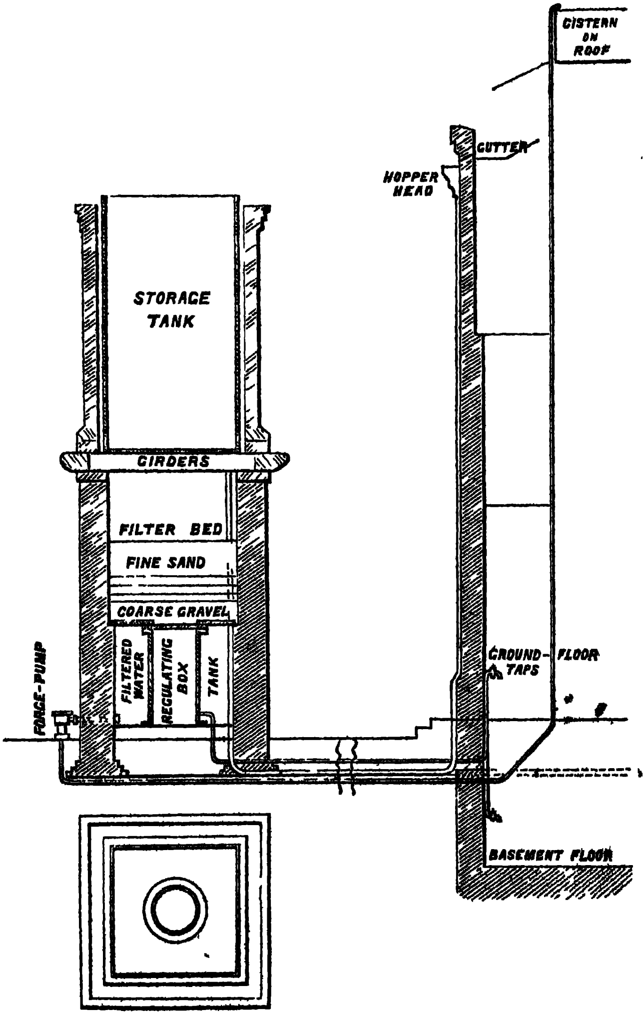
In the discussion of this paper, Dr. Letheby said that a cubic foot of animal charcoal, weighing from 50 to 52 lbs., held within its pores four gallons of water, and that he had found by experiment that it was necessary that the water, to be purified, should remain in contact with the charcoal for at least one minute. In Mr. Byrne's experiments the time had been two and a half minutes. It was stated [illegible] t th[illegible] rate of filtration through the filters of the Water Pu[illegible]fying Company is 400 gallons a day, through a filt[illegible] containing 80 lbs. of charcoal.

Dr. Frankland said he had passed some of th[illegible] don water through a stratum of animal charcoal [illegible] feet thick, at the rate of more than 41,000 gall[illegible] square foot in 24 hours, under a head of 30 fe[illegible] Th[illegible] charcoal was in granules, like coarse sawdus[illegible] and in the above-named instance more than one-ha[illegible] the organic matter in the water was removed; and, o[illegible]cing the rate of passage of the water to one-half, one-fourth, or one-tenth, the proportion removed was scarcely increased. It appeared, from experiments, that wood or other vegetable charcoal is inert in its action on organic matter in water.

Animal charcoal appears to have been applied to the filtration of water with some success by Mr. Atkins, of Fleet Street. The charcoal is reduced to powder and mixed with powdered vegetable and combustible matter; and the combined powder is mixed with liquid pitch, and the mixture worked up and moulded into plates or blocks of any form. By thus moulding the charcoal into blocks, it is at once put into a convenient and portable form; and the mud arrested on the surface is scraped off, after the plate, or frame of plates, or the block, has been removed from the water. For continuous use, a duplicate set is required; as, indeed, is the case in any method of filtration. It would seem, however, that extreme care should be taken in fixing the plates in the grooves, to prevent the water passing through the joint between them. If they were [illegible] be permanently fixed, the joint might be easily [illegible]ented; but, with a moveable plate, we should anti[illegible]pate leakage of unfiltered water between the plate or frame of plates and the sides of the filter.

[illegible]n, however, as indeed often happens, a mansion [illegible] house is without a sufficient supply of water, [illegible]seful quantity may be obtained from the roofs. A m[illegible]arger roof-area, in proportion to the number of pers[illegible] living under it, exists in such cases as this than [illegible]mall houses. If we take a large number of small ho[illegible], we find the average number of persons per house to be, say, five, and we find the average roof-area to be, say, 360 square feet, or it may be in some cases that the average is 400 square feet, or 80 square feet per head of population; but, in the case of a mansion, the comparative roof-area is much larger, even when

Fig. 19.


CISTERN
ON
ROOF
GUTTER
HOPPER
HEAD
STORAGE
TANK
GIRDERS
FILTER BED
FINE SAND
COARSE GRAVEL
FILTERED
WATER
REGULATING
BOX
TANK
FORCE-PUMP
GROUND-FLOOR
TAPS
BASEMENT FLOOR

the visitors are included. It is often as much as 200 square feet for each person; and, taking 18 inches as the available depth of rain-water in an average year, the quantity would be 1875 gallons per head in the year, or, when regulated, 36 gallons per head per week. It is better, in this case, to reckon the quantity per week; because, in order to regulate the quantity, a service cistern must be constructed, to be filled by, say, the chief servant of the household periodically. If the quantity used during a week were equable, day by day, it would be sufficient to make a small cistern to hold one day's supply, and that it should be filled from the storage tank once a day; but, as on some days of the week much more water is used than on others, it is better to make the service-cistern to hold a week's supply. Without some regulation of this kind, there would be no certainty of the storage lasting over a drought; and it is because this regulation cannot be practically and generally maintained in small houses, that the rule of storage capacity of reservoirs cannot be applied. When the water can be regulated, say weekly, the capacity of the storage tank may be 120 days' (average) supply, in the western counties; and may vary from that capacity to twice as much in the eastern counties.

§ VIII.—CONTAMINATION OF WELL-WATER.

The sources of contamination of well-water are:—(1), privy cesspools which are not water-tight, and from which rain-water is not excluded; (2), soakage of the top-water into the ground and thence into the wells, conveying with it refuse matter from the surface; (3), house-drains which lie near the well, and which allow the house-slops to percolate through the joints into the surrounding ground, from which they gradually soak into the well; and (4), unless the drain consists of pipes closely jointed, rats are a frequent cause of contamination of wells near which house-drains lie; for rats seem to have a peculiar instinct in finding their way through the ground direct to water, and, although the water in the well may be out of their reach, it is possible that in their efforts to reach it some of them drop in; but, even if that should not be so, refuse liquids may find their way through the holes they make from the drain to the well.

There are three kinds of wells:—(1), pump-wells, (2), draw-wells, and (3), dipping-wells, and the above-named forms of contamination are common to them all; but a draw-well is liable to contamination of another kind. The cover is necessarily moveable, and is usually on the same level as the surface of the ground. The cover is often left open, and small animals, such as dogs, cats, and rats, sometimes fall

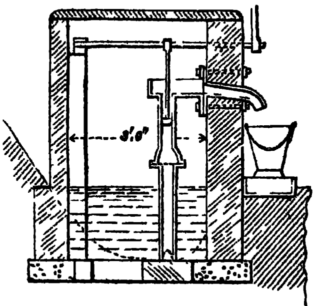
in; and, the occurrence being unknown, the animals decay there and contaminate the water, the cause of the consequent illness of the persons who drink the water being probably undiscovered.

Unless wells be provided with pumps, the rim or edge-curbing should be raised above the surface of the ground, and a step or two made for persons to ascend to draw the water.

Dipping-wells are also subject to contamination from other sources. The cans, buckets, and pails used are set down in dirty places about the house, and the dirt is carried to the well and washed off in the act of dipping. Also, every time anything is dipped into the water, it is stirred up and muddied for the next person who comes. Another source of pollution of an open well-hole is the mischief of children, and where the situation is public this cannot be prevented. A dipping-well the water of which is used for domestic purposes, ought not to be allowed to exist. Every opening should be completely closed, except one for ventilation, which should be protected by a hood, so that it cannot be reached, and another for the overflow of water, which should likewise be shielded; and the water should be procured by means of a pump. These dipping-wells are weak springs, and as the overflow of water may probably be frequent, a cattle-trough may be so placed as to receive the overflow: in public places this is of great use. The pump should be wholly enclosed within the well, and a horizontal shaft or spindle should traverse the well from wall to wall, carrying upon it an arm to work the pump-bucket, having only its end projecting through the wall, upon

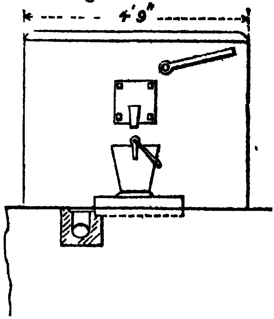
which is fitted a simple lever or handle 18 inches or so in length. Being wholly enclosed or bricked up, the pump barrel should be lined with brass or gun metal, and truly bored out, and, indeed, well and truly fitted in every respect, so as to prevent the need of frequent repairs, which is a too common need of many pumps.

Fig. 20.



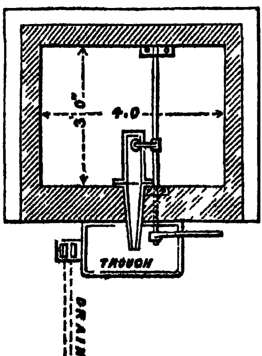
SECTION

Fig. 21.



ELEVATION

Fig. 22.



PLAN

Figs. 20, 21, and 22, show respectively a section,

an elevation, and a plan of such an enclosed pump, the handle alone being outside the brickwork. Under the spout is a dog-trough, 24 in. × 12 in. × 4 in., across the middle of which are two iron bars, upon which the bucket or pail is set. At one end of the trough there is a lip, an inch below the edges of the trough, over which the surplus water flows into the drain, through a small grating. The pump, and the shoot or spout, are of cast-iron; the working barrel lined with brass, and the foot-valve is also of brass. It is important that this valve should be well fitted, because of the small head of water upon it to keep it tight. Two lugs are cast upon the pump barrel, one near the top and the other near the bottom, which are bolted to two cross pieces of wood, built into the brickwork, to hold the pump steady.

These pumps are made at a cost of about 50*s*. each, and the rest of the work costs about the same. As to the trough, it should be a shallow one, to hold about 3 or 4 inches depth of water only, for if it be made deep enough to dip into, the children who are sent for water for the household—and it is children mostly who fetch the water under the circumstances now under consideration—would fill their pails with the contaminated water of the trough, after the well-water is exhausted, which is a very common occurrence in dry weather.

Weak springs, as many of these are, although the water may be of good quality, yield but a very inadequate quantity for the number of persons resorting to them. While they remain open dipping-places, persons who come to fetch water, and see the depth insufficient to dip into, wait (sometimes for a long time)

until they can dip their pail or other vessel; but when the water is boxed in and a pump fixed, they exhaust the supply of water quickly, and are too apt to say that the new pump is no benefit to them, or that they would rather have the old dipping hole again. But as this arises from thoughtlessness, time will probably convince them that they had better have of good quality what water the well-hole yields than have it polluted.

It is more difficult to arrange a proper water-supply in a rural district than in a town. Rural sanitary districts contain many aggregations of population of 2,000, 3,000, and 5,000; and it is these places which are the most difficult to deal with in respect of the water-supply. Take, for instance, one parish of, say 4,000 population, in a dozen parishes constituting the Rural Sanitary District of, say 20,000 or 30,000 population, living on about as many acres of ground: three-fourths of the population of the parish may be congregated on 100 acres, the other thousand being distributed in something like the following manner:—100 at A, 200 at B, 300 at C, and 400 at D. Now, leaving out of the question how three-fourths of the population of the parish may be supplied, those designated A, B, C, and D, will probably all procure water for domestic purposes from sources liable to contamination from passing persons and animals, whether accidental or wilful. But supposing a satisfactory water-supply to be arranged for the main portion (say the 3,000) of the population, it would probably not pay, at the current water-rate, to supply the small outlying places—the other fourth; although, living within the

same sanitary district, they may very properly say they have the right to be supplied equally with those who live more centrally in the same district, providing they are willing to pay the current water-rate on the value of the house. But if the sanitary authority must include these outside people, the water-rate upon those more centrally situated must be increased, so that an average rate may be struck for the whole district. It is therefore advisable to protect and render as useful as possible all the small sources of water in the outlying parts, so that the inhabitants may procure, in a tolerably pure state, whatever quantity these small sources yield.

There is little or no doubt that the average rate of mortality of some of the Sub-districts of Registration is unduly swelled by excessive mortality in small outlying places, and that if these could be kept within the average of the district that average would be considerably less than it is now; and who knows how far the unwholesome water of these outlying places contributes to swell the bill?

The section of the Act which relates to this subject is the 70th, as follows:—"On the representation of any person to any local authority that within their district the water in any well, tank, or cistern, public or private, or supplied from any public pump, and used or likely to be used by man for drinking or domestic purposes, or for manufacturing drinks for the use of man, is so polluted as to be injurious to health, such authority may apply to a court of summary jurisdiction for an order to remedy the same; and thereupon such court shall summon the owner or

occupier of the premises to which the well, tank, or cistern belongs, if it be private, or in the case of a public well, tank, cistern or pump, any person alleged in the application to be interested in the same; and may either dismiss the application or may make an order directing the well, tank, cistern, or pump, to be permanently or temporarily closed, or the water to be used for certain purposes only, or such other order as may seem to them to be requisite to prevent injury to the health of persons drinking the water."

The court may order the water to be analysed, and if the person on whom an order is made fails to comply with the same, the court may, on the application of the local authority, authorise them to do whatever may be necessary in the execution of the order, and expenses may be recovered from the person on whom the order is made.

SANITARY WORK

IN

THE SMALLER TOWNS AND IN VILLAGES.

PART II.

DRAINAGE.

SANITARY WORK

IN

THE SMALLER TOWNS AND IN VILLAGES.

PART II.

DRAINAGE.

§ IX.—HOUSE-DRAINS AND SEWERS.

Definition.—Drains and Sewers are sometimes spoken of indiscriminately, but it is necessary, for convenience sake, to make a distinction. Again, house-drains and land-drains are distinct in their functions, the one draining surface-water and the other ground-water. We define a house-drain to be a channel (whether open or covered) which conveys away from a house, or from a few houses, the refuse liquids, together with such solid matter as may be in suspension and solution in them; and a sewer to be a channel (whether open or covered) which receives the contents of two or more house-drains; a main sewer, one which receives the contents of two or more other (subsidiary) sewers; and a trunk or outfall sewer, one which receives the contents of all other sewers belonging to the same system.

Sewers may act as land drains.—A sewer may, by constructing it in a certain manner, be made to admit ground-water; and, in argument whether a sewer should be made to remove the wetness of ground through which it may be laid, the subject may be argued on the understanding that a sewer, made in a certain manner, will act as a drain, while, if made in a certain other manner, it will be impervious, and therefore not a drain-sewer. It is a question to be determined rather by the doctor than by the engineer whether the dampness of ground under and near dwelling-houses should be removed: if so, the only question for the consideration of the engineer is how far the drainage of the ground may assume the form of a run of water sufficiently quick to carry with it fine particles of earth or sand into the sewer, and so induce a settlement of the ground and consequent danger to the stability of buildings. In merely damp ground this would not occur, and it is in this kind of ground where the method seems most beneficial.

When the sewage (sewage being that which flows through drains and sewers, whatever it may consist of) of several houses belonging to different owners is brought into one drain, before it enters a sewer, the drain is a main drain, as when, by agreement between owners of adjoining houses, one drain, laid along the backs of their respective houses, drains them all before it debouches at the lowermost into a sewer.

Another method of distinction is that drains are those channels which belong to houses as private property, without reference to the number of houses drained by each, and that sewers are such channels as

belong to the public. Practically, the results of the two methods coincide in most cases.

Old Water-courses.—In Rural Sanitary Districts perplexing questions arise as to whose duty it is to repair, alter, or amend certain watercourses into which house-sewage and road-water have been turned from time to time, and which lie through private lands. These were originally, no doubt, the natural outlets of the rainfall, and, as such, belonged to the owners of the adjoining land, each one having the use of it as far as his land extended, and being responsible for its condition. So long as that which came into such a water-course was rain-water only, all that was necessary was to provide for its passage, without reference to the form of the channel; but when houses have been built within the watershed of such a channel, the sewage has been from time to time turned into it by house-owners who have had no original rights in the land adjoining it. This has come about in the following manner:—Roads have been formed in a direction across this original water-course, the road ditches having their outlet into it. Houses have been built adjoining the road. The open ditches having been found to be inconvenient, a culvert has been laid to carry off the road-water, and the ditches have been filled up. This has been done either in whole by the parish vestry or in parts by the house-owners as far as their respective frontages have extended, the parish authority completing the culvert in other parts. Then, from time to time, the house-sewage has been turned into these culverts, and so the main watercourse has become an open sewer, used by

the public; but its form is such that the sewage lodges in it and becomes a nuisance. Presently the sanitary authority is appointed, and it is desired that the nuisance shall be done away with. The question then arises—Is this a public sewer? for if so, the sanitary authority ought to amend its form so that the sewage may be properly carried off.

The usual remedy, and an effectual one, for a case of this kind, is to lay an intercepting sewer for the house-sewage, taking it along such public roads as may be practicable and convenient, and through private lands where it may be necessary, under the powers of the Act. It is one of the principles of sewerage that natural watercourses should not be converted into sewers, but should be left to perform their proper function of carrying off rain-water, and especially storm-waters. Such an intercepting sewer is, of course, laid by the sanitary authority.

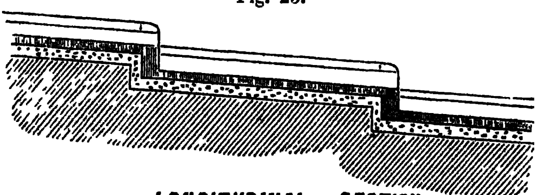
There are cases, however, where the area of ground naturally draining into a watercourse of this kind is small, which may be treated as exceptions to the rule, and where such a watercourse may be continued to be used as a main sewer, either covered or open, or covered in some parts of its course and open in others.

In such a case, where the ground is very steep, and where floods have formerly torn up the bottom of the old water-course and brought down the sides, but where, nevertheless, there would have been great difficulty in carrying the sewage in another direction by an intercepting sewer, I have deemed it advisable to allow the old watercourse to continue to be used as a sewer. To prevent sewage lodging in the rough bottom of the

old watercourse, I have laid in a brick invert, on concrete, as shown in figs. 23 and 24. To check the too great rush of water in flood times I have formed the bottom in steps, as shown.

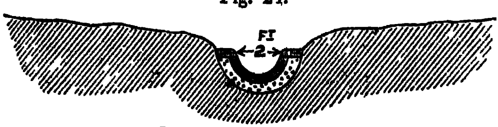
In steep ground, such as this, a covered sewer is almost like a flue, up which the gases ascend rapidly from the lower levels, and blow out at any opening there may be, and in this case the lower end of the sewer is covered, and is in communication with other sewers at lower levels, so that in the part now under notice, and where it was not absolutely necessary to

Fig. 23.



LONGITUDINAL SECTION

Fig. 24.



CROSS SECTION

cover it, it has been left wholly open, thereby breaking the connection of the covered sewers at the lower levels with those at the higher levels.

House drains everywhere necessary.—The necessities of urban and rural sanitary districts are different in degree but not in kind, and it is the degree that is the important thing to be considered in each rural sanitary district, according to the density of

population and other circumstances. This question of degree, however, applies to works of combination, such as sewers, and not to individual works, such as house drains. Every house in a rural sanitary district requires a drain to carry off the house-slops, as well as every house in a town; but the sewage may in some cases be satisfactorily disposed of without any system of sewers, where the houses are widely separated from each other.

Properties of a sewage flow.—The properties of a sewage flow are (1) its viscidity; (2) its velocity, which depends upon two subsidiary properties, viz., the hydraulic mean depth of the stream and its inclination; and (3) the scouring action of the stream upon the bottom of the channel.

In respect of the first of these we may take it to be the same as that of water.

In respect of the second property, if the cross sectional area of a stream be divided by the width of its cross section, measured along its bed, the result is the hydraulic mean depth; and the greater this depth the greater is the velocity, if the inclination remains the same.

Velocity of a sewage flow.—The flow of a liquid is influenced by the friction between it and the channel through which it runs, and it is retarded, more or less, accordingly as the extent of the surface of the channel with which it flows in contact is great or small, in relation to the quantity of liquid flowing through the channel. The quantity of liquid discharged by any channel of given size, as a pipe of given diameter, is the result of the sectional area

of the stream multiplied into its velocity. It is desirable that the velocity of the sewage should be considerable. In circular pipes the least extent of surface is offered, in relation to the quantity discharged, and therefore the least obstruction to the flow of sewage, when the sewage half fills the pipe, in all cases within the limits of practice.

Solid deposit.—The third property is necessary to be considered so that stoppages of the sewer or drain may not take place from the accumulation of solid matter. In Beardmore's "Hydraulic Tables" it is stated that

30	feet per minute	will not disturb clay with sand and stones.	
40	,,	will sweep along coarse sand.	
60	,,	,,	fine gravel.
120	,,	,,	rounded pebbles.
180	,,	,,	angular stones.

These, except the first, coincide with Du Buat's experiments.

In Rankine's "Manual of Civil Engineering" are stated, not the velocities which will move solid matter along, but the greatest velocities of the current close to the bed consistent with its stability; thus—

Soft clay	0·25	feet per second.
Fine sand	0·50	,,
Coarse sand and gravel as large as peas .	0·70	,,
Gravel as large as French beans . .	1·00	,,
Gravel 1 inch diameter	2·25	,,
Pebbles 1½ inch diameter . . .	3·33	,,
Heavy shingle	4·00	,,

Mr. Neville gives the following in the third edition of his "Hydraulic Tables, Co-efficients, and Formulæ," recently issued by the publishers of this work.

Speaking of *rivers*, he says (p. 258), "The mean velocity must not be too quick, and should be so determined as to suit the tenacity and resistance of the channel, otherwise the bed and banks will change continually, unless artificially protected ; it should not exceed

25 feet per minute in soft alluvial deposits.		
40	,,	clayey beds.
60	,,	sandy and silty beds.
120	,,	gravelly.
180	,,	strong gravelly shingle.
240	,,	shingly."

Although in the regimen of rivers it is an object to restrict the velocity so that the materials of the bed may not be worn away, and in sewers it is an object to increase the velocity so that deposit shall be carried away, still a useful comparison may be made between this table and the others herein given.

Mr. Wicksteed made some experiments with a channel having a semicircular bottom (Du Buat had operated on a channel sometimes rectangular and sometimes trapezoidal, whose greatest breadth was 18 in., and depth from 3 to 9 in.), and he found that with a bottom velocity of 12½ in. per second, coarse sand, small pebbles, and rounded stones, and pieces of brick 2 in. diameter, were carried along, the larger ones moving rapidly and stirring up the sand and small stones, which moved slowly. With a velocity of 21¾ inches per second iron borings, together with all the previous substances, and pieces of brick 3 in. across, were carried along. In these experiments the fall of the surface of the water and the bottom of the channel were the same, viz., 1 in 189.

Experiments were then made with a level bottom, and a sufficient supply of water admitted into the channel to produce a surface velocity of 32¾ in. per second, which would indicate a bottom velocity of about 20 in., or, according to some authorities, 22 or 23 in., and with this velocity, on a level bottom, half and three quarter bricks, together with the substances before named, were rolled along, turning over and over.

Surface, mean, and bottom velocities.—It is difficult to measure the bottom velocity in any actual stream, and the experiments of different persons do not show any close agreement in the results arrived at, in respect of the relation which the bottom velocity bears to the surface velocity.

In Dr. John Robison's "Mechanical Philosophy" it is stated that the differences between the velocities at the surface and the velocities at the bottom of streams are proportional to the square roots of the velocities at the surface. The mean velocity is the arithmetical mean between the surface and bottom velocities. In a general way, if unity be taken from the square root of the surface velocity in inches per second, the square of the remainder is the velocity at the bottom.

Dr. Rankine says that the least velocity, or that of the particles in contact with the bed, is about as much less than the mean velocity as the greatest velocity is greater than the mean, that is, that the least, the mean, and the greatest velocities may be taken as bearing to each other nearly the proportions of 3, 4, and 5.

Mr. Bazalgette stated, in a paper read at the Institution of Civil Engineers, on the metropolitan main drainage, that he had designed the work so that there

should be a mean velocity of not less than 1½ mile in an hour, when the sewers run half full, which is 132 ft. per minute, or 2·2 ft. per second, the bottom velocity of which, according to the above-named ratio, would be 99 ft. per minute, or 1·65 ft. per second.

According to the experiments precedently named this bottom velocity would "sweep along fine gravel," or "gravel as large as French beans," or "coarse sand, small pebbles, and rounded stones, and pieces of brick 2 in. diameter."

From these and from our own observations we may say that the bottom velocity of a sewage stream ought never to be less than 18 in. per second, or the mean velocity less than 2 ft. per second. With the quick fall which may usually be given to house-drains a mean velocity of 3 ft. per second may easily be obtained, if the pipes be not made too large.

Qualities of house drain and sewer pipes.—One of the first requisites of a house-drain or sewer pipe is that it be perfectly circular, and another that it be smooth. The kind of clay of which drain-pipes are sometimes made, and the mode of manufacture, are such that during the process they fall out of shape and become non-circular at the ends. This irregularity of shape in adjoining pipes in the same drain causes obstructions to the solid matter of the sewage, obstructions which are cumulative, and which are not found out for a long time after their commencement, causing a generally foul state of the drain, and one from which large quantities of foul gases are given off, which travel upwards along the drain to the house.

There are three kinds of earthenware pipes in use for house-drains and sewers.

1. "Earthenware" pipes, which are made at many brickyards, but of one kind of clay only at each. Very few of these stand the heat necessary to vitrify them thoroughly and yet retain their shape, and they cannot be made so smooth inside as is desirable for house-drains and sewers.

2. Stoneware pipes. These are made of a mixture of clays which burn mostly of a light colour, and sometimes there is an admixture of previously burnt clays broken up, and other substances, and the mixture of which they are made will stand great heat in burning, while yet the pipes mostly retain their form. These pipes can be, and mostly are, glazed with common salt during the later stages of firing. They are usually 2 ft. in length, excluding the socket, which is 1½ in. deep in the 3-in. and 4-in. pipes, 1¾ in. deep in the 6-in. pipes, 2 in. deep in the 9-in. and 12-in., and 2¼ in. in the 15-in. pipes. The thickness of the 3-in. pipes is usually ⅜ in., of the 4-in. pipes ½ in., 6-in. pipes ⅝ in., 9-in. pipes ¾ in., 12-in. pipes 1 in., and 15-in. pipes 1⅛ in., and those made by Messrs. Stiff and Sons weigh respectively about 12 lbs., 16 lbs., 29 lbs., 52 lbs., 86 lbs., and 126 lbs.

Other pipes are made of fire-clay, and these are usually thicker than stoneware pipes, except the smaller sizes of 3 in. and 4 in., which are the same.

When there may be a special reason for requiring greater strength to resist external pressure than the ordinary stoneware pipes will resist, or than it would be prudent to subject them to, fire-clay pipes may be made of any thickness required; but stoneware pipes, as well as some kinds of earthenware pipes, will resist

considerable external pressure. When Mr. Rawlinson some years ago read a paper on the drainage of towns at the Institution of Civil Engineers, Mr. Doulton said he had tried the strength of some pipes made by his firm, with the following results. The pipes experimented on were two feet long; each pipe was supported at the ends on blocks; a piece of wood twelve inches long was laid on the middle, and the weight was gradually increased until fracture ensued. The following were the results :—

Diameter of pipe.	Thickness.	Weight on 12 in. square.		Weight over the entire surface of the pipe.		
		cwts.	qrs.	tons.	cwts.	qrs.
15 in.	$\frac{7}{8}$	31	3	7	1	1
12 in.	$\frac{3}{4}$ and $\frac{1}{16}$	53	3	8	13	2
9 in.	$\frac{3}{4}$	64	3	8	18	3

But it would not be prudent to accept these as the breaking weights of all stoneware pipes of like diameter and thickness, even of the same make, for one or a few in a great number might fail with very much less weight. Moreover, it would be contrary to all engineering practice to allow an actual weight even to approach any known breaking weight.

Inclination of house-drains.—There is usually no difficulty in giving a sufficient fall to house-drains, if the pipes be true in form and evenly laid (and no fall whatever will compensate for defects in either of these respects). A moderate fall, and yet a sufficient one, is 1 in 60, or 2 in. in 10 ft., for the body of the drain, and 1 in 30 for the branches.

Sizes of house-drains—The proper size of a sewer

or drain must be determined upon a consideration of the laws of hydraulics, moderated by knowledge derived from experience. This is necessary; for by the former alone we should find that a pipe of but two or three inches diameter is sufficient for half a dozen houses, even with the small inclination sometimes given to house drains, but we know by experience that the diameter should not be less than six inches, on grounds distinct from hydraulic laws. But the requisite size of a house drain is often over-estimated. A pipe six inches internal diameter is sufficiently large for the drain of the largest house, and it is not too large for the smallest house. A house drain frequently has several branches, and each branch may be four inches diameter. A 4-in. pipe would indeed be sufficiently large for the whole length of the drain in respect of its capacity to carry off the quantity of sewage running from the house, but from the carelessness of persons a solid article—much too large and heavy—sometimes gets into the drain, and in a 4-in. pipe this fills up too much of the space to allow the sewage to pass it. If, then, the obstruction takes place at some unknown part of the body of the drain there is great trouble in finding it, but when each individual branch is but 3 in. or 4 in. diameter a solid article is more likely to be caught before it gets as far as the 6-in. pipe, and when a stoppage is caused by such an article its position may generally be ascertained to be at or near an inlet of the drain, and may be removed at once without much searching. If, however, it get through the branch, and the drain be 6-in. diameter, it will probably not obstruct the sewage

altogether, but will be gradually moved down towards the end of the drain by the occasional flushes of water, and will probably be carried down to the outfall without further inconvenience.

For this reason the body of a house drain should not be less than 6 in. diameter, although the branches may be 4 in.

A concise and useful formula for our present purpose is that of Eytelwein, given in Tredgold's "Tracts on Hydraulics," viz., that the mean velocity per second of a stream of water of similar form to those we are now considering is about nine-tenths (more accurately ten-elevenths) of a mean proportional between the hydraulic mean depth and the fall in two English miles, supposing the channel to be prolonged so far. The mean velocity per second of any such stream may therefore be represented generally thus:—

$h =$ the hydraulic mean depth,
$f =$ the fall in two miles,
and $v =$ the mean velocity sought.
When $v = \cdot 9 \sqrt{hf}$,

or, as it is more convenient to take small quantities like these per minute, $v = 54 \sqrt{hf} =$ the mean velocity per minute; and this velocity multiplied into the sectional area of the stream gives the cubic quantity discharged.

Discharge of a 6-in. pipe.—The velocity in a 6in. pipe running half full, and having a fall of 1 in 60, would be fully 250 feet per minute, and this multiplied into the sectional area of the stream would give a discharge of 24 cubic feet per minute, or 150 gallons.

If we take the fall to be 1 in 120, $f = 88$, and $9\sqrt{hf} =$ a mean velocity of nearly 3 feet per second, or 180 per minute, which would give a discharge of fully 100 gallons per minute.

No household discharges so much sewage as this. The velocity, however, will be less than that above stated so long as the sewage does not half fill the pipe, which it will seldom do in a 6in. pipe, even when it drains half-a-dozen houses, with a fall of 1 in 60, unless the rain-water of an unusually large area be turned into it.

The only direct rain-water that it is necessary to turn into a house drain is that falling upon the ground surface of the back premises of houses. That falling upon the roofs may be, and certainly should be, caught and stored for use, and sent into the drains after use. As to the area of the ground surface of the back premises of houses drained directly into the house drains, numerous observations and measurements show that it seldom exceeds the area of the house roof, and this, as has been before stated, has been found by the measurement of several thousand house-roofs to average about 360 square feet. If we say that the direct rainfall to be carried off by the house drain as fast as it falls is that due to an area of 360 square feet, that is rather to overstate than understate the average area of small houses.

A house drain should carry off as fast as it falls the greatest rainfall from the area draining directly into it, together with the greatest quantity of house-sewage that may be discharged at the same time. If we take the quantity of water resulting from a depth of rain

of 2 in. in an hour over an area of 360 square feet as the quantity to be carried off, the discharge to be provided for would be 60 cubic feet in the hour, or 1 cubic foot per minute. But say that during some short part of the hour the quantity might be twice the average, or 2 cubic feet per minute.

The maximum quantity of sewage discharged per minute from one house does not exceed 2 cubic feet per minute, and that only very rarely.

If we suppose this to occur at the same time as the heavy rainfall above stated, which is not impossible, the quantity the drain must be capable of discharging is 4 cubic feet per minute per house.

Referring to the calculated discharge of a 6-in. pipe when half full, and with a fall of 1 in 60, viz., 150 gallons per minute, or 24 cubic feet, we see that with that fall a 6 in. pipe is sufficient for six houses; but how often do we see and hear of owners of house-property being advised to lay down 9-in. pipes when several houses are to be drained by one drain, and sometimes even when only one house is to be drained? It is quite as easy to fall into the error of laying down too large a pipe as one too small, and of the two that error is the more often made.

The few calculations given above are not intended to prove anything which is not already well known to those accustomed to this kind of work, for they neither make nor require such calculations, but only to prove to those who are inclined to lay down pipes of too great size that they not only do no good by it, but harm.

The causes of stoppages of house drains and sewers.— Certainly many drain and sewer pipes have becom

choked with solid sewage, and the fault has been mostly attributed to the supposed too small size, whereas the proper reason has more probably been that they have been badly laid, badly jointed, or of irregular form. As to the form of drain pipes it has already been said that they should be truly circular. As to the laying, sufficient care is often not taken to make the bottom of the trench of uniform inclination; and as to the jointing, carelessness in this respect is the chief cause of stoppage.

In very stiff and retentive clay sewage cannot escape far away through bad joints, but it is certain (from actual observations) that wherever the ground is at all porous, large quantities of liquid escape through imperfect joints of drain and sewer-pipes. The liquid is the carrier of the solid portions, which have a constant tendency to settle to the bottom of the pipe, and if the liquid be insufficient in quantity to cause the necessary velocity (that is, if it be allowed to escape at the joints), the solid part of the sewage necessarily settles and chokes up the drain. And to be convinced of the extreme importance of attention to the jointing, it is only necessary to consider that during all the time this accumulation of solid sewage is taking place the drain is, in fact, a long cesspool, one end of which adjoins a dwelling-house.

When 6 in. pipes have become choked with solid sewage it has often been supposed that that is too small a size for a house-drain, and 9 in. or larger pipes have been recommended as a remedy, instead of attributing the fault to its probably true cause—the inefficient jointing of the pipes. But if a drain be so

laid that stoppage occurs from accumulation of solid sewage, the sooner the stoppage takes place the better, for as it takes a longer time to fill a 9 in. than a 6 in. pipe with solid matter, so much the longer does the injurious action go on.

Jointing.—The pipes of house-drains and sewers are usually jointed with clay or with cement. Clay is preferable where there is a probability that a pipe may require removal in order to insert a junction pipe at some time after the drain has been laid. When clay is used it should be well worked together outside the trench, and made of a consistency sufficiently tough to allow a band of it a foot long to be suspended without breaking. A band of well-tempered clay being thus made, by taking a lump of it and rolling it out on a planed board and flattening it out to a width of 2 in. and a thickness of ½ in., it is to be laid round the lower half of each socket, after the pipe has been laid in place, before the spigot-end of the next pipe is inserted.

A good pipe layer will draw up the spigot-end of each pipe until it touches the upper part of the socket; and then, when the pipe has been drawn "home," will let it drop vertically upon the clay band in the lower half of the socket, thus avoiding disturbance of the jointing material, and leaving no space between the ends of adjoining pipes.

When cement is used there is danger of its getting through into the interior of the pipe, there setting, and causing ugly lumps and obstructions. To prevent this, Mr. Latham recommends that several strands of tarred gaskin, of sufficient thickness to fill the socket tightly, should be forced into it.

Another method is to fill the lower half of the joint with mastic. Almost any finely disintegrated material mixed with a sufficient quantity of melted coal-tar pitch, with which is mixed also a proportionate quantity of the oil of the tar, makes a substance at once indissoluble in water, or in the dilute acids contained in sewage, and sufficiently dense to make a water-tight joint.

The upper half of the joint should be left open (whatever the lower half be jointed with) to drain the ground, a barrowfull of gravel or other hard dry material, as brick rubbish, being placed over each socket before the earth is filled into the trench.

Fig. 25.

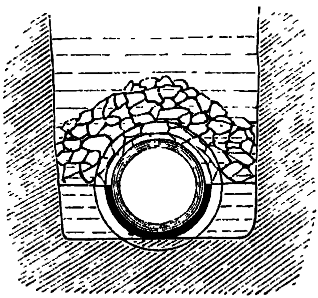
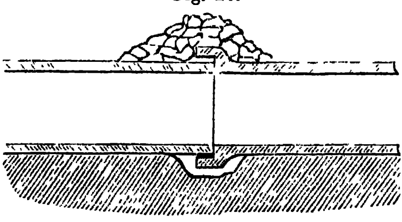


Fig. 26.



Messrs. Doulton have recently introduced a form of

joint which may probably be made efficient, "casting upon the spigot and in the socket of each pipe, by means of moulds prepared for that purpose, rings of cheap and durable material, which, when put together, fit mechanically into each other." But in these pipes, as made, the joint is close all round, and does not admit of the ground being drained through the upper half of the socket.

In June, 1869, a paper was read before the Geological Society of London by Mr. William Whitaker, B.A., F.G.S., on the connection of the geological structure and the physical features of the south-east of England, with the consumption death-rate. The subject had already been discussed in detail (Report of the Medical Officer of the Privy Council for 1867, pp. 14—17, and 57—110), yet Mr. Whitaker thought it would be well to state the chief facts of the case from a geological point of view, the method of investigation followed, and the conclusions come to.

Dr. Buchanan had previously been appointed by the Privy Council to inquire into the results of sanitary improvements in England. With this object he visited twenty-five large towns in which various works, designed to promote the public health, had been for some years in operation, and his investigations led to the conclusion that consumption had been very materially affected. This disease, however, had not decreased in all cases, and on examination it turned out that the lowering of the consumption death-rate went along with the decrease of water in the subsoil by improved drainage; and this led Dr. Buchanan to suggest that it might be well to see whether natural

causes which affect the saturation of the subsoil, had not also some connection with consumption; or, in other words, whether places on those geological formations which allowed the free drainage of water would not have a lower consumption death-rate than places on less pervious or damper beds.

As in the south-east of England the surface-deposits of gravel as well as the regular formations of clay and other strata were shown upon the geological maps, that part of the country was chosen for investigation, and divided into 58 districts, Mr. Whitaker being associated with Dr. Buchanan in the inquiry. The plan was "to select out of the 58 districts such as are most comparable with each other in regard of their position and geological structure, and to see how their phthisis is affected by the perviousness or imperviousness, elevation or lowness, slope or flatness, in the members of such more limited series." The results were as follow:—

(1) On pervious soils there is less consumption than on impervious soils.
(2) On high-lying pervious soils there is less consumption than on low-lying pervious soils.
(3) On sloping impervious soils there is less consumption than on flat impervious soils.
(4) These inferences must be put along with the other fact, that artificial removal of subsoil water, alone, of various sanitary works, has largely decreased consumption.

From which follows the general inference, that wetness of soil is a great cause of consumption, no other

condition having been found, in the course of these inquiries, to go along with the consumption death-rate to any great extent.

I have introduced these quotations from Mr. Whitaker's paper (which was given in the "Geological Magazine" of November, 1869, and published in separate form by Messrs. Trübner & Co.), in support of the assertion that the upper part of the joints of sewer-pipes should be left open.

It is necessary, however, to point out that these openings will not receive any water—or will not receive much of the water—until the ground below the pipes, and up to the level of their middle, has become super-saturated; the water then overflows into the pipes through the openings. This points out that the sewers should be laid at a considerable depth, for, if not, the water would sink below them and stand at some uncertain level, which might be but little below the sewers, and thus the drying of the ground would not be attained.

Mode of Laying Pipes.—A common way of laying pipes, but a very wrong one, is to lay them down upon the bottom of the trench so that the bearing points are the two ends only, the body of the pipe being unsupported. Two serious defects in the drain occur from this. Firstly, the weight squeezes out the clay or cement with which the joint is made, and the spigot-end of one pipe falls below the socket-end of the next one, causing an inequality of the bottom at every joint; and, secondly, the pipes thus lie hollow, being supported at the two ends only, and when the trench is filled-in the super-

incumbent weight has a great tendency to break them. They should lie solidly all along the body of the pipe upon the bottom of the trench, a hole being made to receive each socket. If the bottom of the trench be trimmed to an even gradient the pipes will then lie concentrically, and the joints can be properly made.

Refilling the trench.—In refilling the earth into the trench the small stuff should be first thrown in, and the spaces between the pipe and the sides of the trench should be well filled, so as to prevent future sinking by leaving hollows under the sides of the pipes.

The bottom of the trench having been filled up to the middle of the pipe with the most retentive of the earth thrown out, gravel should be thrown in, all along the trench, sufficient to cover the sockets of the pipes; but where so much gravel is not procurable within reasonable distance, sufficient at least should be procured to block the front of the open sockets and prevent dirt falling in.

The remainder of the filling-in should be done in regular layers of not more than 6 inches in depth, and each layer should be well rammed before another is thrown in, except when the ground consists of gravel or sand, in which case, or in either of them, ramming is useless. The best means of consolidating dry sand is to wet it, and as to clean gravel it will settle of itself into its own position. But ground consisting of clayey gravel or gravelly clay is often met with, and in such cases ramming is necessary. One rammer or punner should be employed for every man filling in.

If the ground in which a sewer is laid consists of a

bed of sand, precaution is necessary to prevent it being carried into the drain or sewer through the upper part of the joints of the pipes which may be left open, as has been said, and in this case the gravel or small stones previously mentioned as to be placed in front of the upper part of the socket joints of the pipe, should be so placed as to act as a filter to the sand, and so prevent its entry into the pipe. But if the ground be of the nature of a quicksand the joints cannot be left open.

Bad Ground.—The possible existence of a quicksand bed at the depth at which it may otherwise be advisable to lay a sewer is one of the strongest reasons why numerous trial holes should be dug to the intended depths at intervals along the lines of intended sewers. If the sewer be begun and continued with such a gradient as brings the bottom into a bed of quicksand at some higher portion of the work, it must be continued at that gradient, however difficult and expensive the work may be; but if this had been foreseen it might probably have not been difficult to make the gradients such as would have avoided the necessity of laying the invert of the sewer in such ground. But whenever ground of this kind is met with, stable litter will be found useful, to pack in behind the poling boards and to drive in between them.

If, with all precautions of close-timbering and the use of stable litter, tow, or cotton waste, the ground still rises in the bottom, some special means of carrying off the water, other than by pumping, must be adopted; but no general method can be stated which would answer in all cases. A bed of concrete would

answer probably in most cases if the movement of the water could be prevented, and so prevent the lime or cement being washed out before the concrete has had time to set. Sheet piling, or close planking, has to be resorted to sometimes. Indeed the expedients are numerous. They are all expensive, and a few yards of such work cost more than a great many trial holes. Mr. Reade of Liverpool adopted a method which would answer if it would not have the effect of carrying away the sand with the water, and so either blocking up the waterway or carrying the sand clean away to the outfall, the result of which would probably be a settlement of the ground near the sewer. The method was to lay in the bottom half-round pipes with the flat side downwards, or, rather, pipes of the form of the letter ⌓ reversed, through which the water ran away, the sewer-pipes being laid on the backs of these drain-pipes, in saddles, the two lines of pipes breaking joint.

Taper Pipes.—In Shropshire taper pipes are made, 20 inches long, the internal diameter of the larger end being slightly greater than the external diameter of the smaller end, allowing the small end of one pipe to enter the large end of another. I am inclined to think that this shape is better than abrupt sockets for steep ground, say, where the inclination exceeds about 1 in 30, as it often does in hilly ground, The advantage of this form is that the sewage has a clear drop from the end of one pipe into the next one.

The series of steps thus formed is very useful in checking the too great rush of sewage where the descent is continuous. Hitherto these pipes have been

used chiefly for land-drains. They are made of the common clay of the locality, which is of better quality for pipes than most other clays with which I am acquainted. Socket-pipes, of 6 in. and 9 in. diameter, are made of the same clay, but they are not salt-glazed, and are somewhat rough internally, and somewhat porous. To remedy this and yet make use of local materials, which I think should always be done if possible, I have treated them after the manner of Dr. Angus Smith's process, dipping them into the melted pitch of coal tar. The raw tar may be used if turpentine be added as a drier, say, half a pint to a gallon of tar. The process is not an expensive one.

Dead Ends of Sewers.—In cases where stoppages have occurred near the upper ends of sewers—the dead ends,—the quantity of liquid is often not sufficient to produce such a velocity of the whole sewage as will carry along the more solid part, which settles gradually until it fills the pipe. For this reason the sewage of several of the uppermost houses on each side of the sewer, say half a dozen, should be collected in one 6 in. pipe before its entry into the sewer, wherever that is practicable. A flushing tank is desirable at every dead end of a sewer, but where the sewage of some dozen houses cannot first be thus collected, it is essentially necessary.

One of the chief causes of stoppage of drains and sewers in which there is an insufficient run of water is the fine sand used at public-houses to scour the metal pots, and for other purposes. This, being

used in large quantities, soon chokes up the trap in the back-yard or scullery, and surreptitious means are often resorted to to save the trouble of frequently emptying the trap.

Drains under House-floors.—In rural sanitary districts the drain seldom need be laid under a house-floor, but may, in most cases, be laid altogether outside the house. In this case the pipe trench may be refilled with the material excavated, but when it is necessary to lay the drain under a house-floor it should be surrounded with puddled clay or with concrete, to prevent the possibility of escape of foul air from it through the joints into the house, and especially so when it lies under a boarded floor.

Junctions of Drains and Sewers.—The junction of a house-drain with a sewer, or the junction of a branch with the house-drain, should in every case be turned in the direction of the flow of sewage in the channel with which the junction is made, and should never enter it at right angles. For this purpose junction pieces are attached to pipes in an inclined direction, into which, when the general direction of the drain or branch is required to be at right angles with the sewer or the drain, a bend pipe may be inserted, which will bring the lead of the pipes into the required direction.

The direction of a drain or sewer, however often it may be necessary to change it, should always be in straight lines, joined with bend pipes. Straight pipes cannot be laid in a curved direction with any proper regard to good jointing.

Terminations of House-drains.—The points up to which separate branches of a house-drain are required to be laid are, in general, as follow. The cellar; the scullery sinkstone; the lowest part of the yard or paved surface about the house, to receive the rain-water or surface-drainage; the water-closet, if there be one; and, in large houses, the butler's pantry. The drain should be brought up from its lower end of such a depth as to allow the extreme end of the farthest branch to be not less than 2 feet below the surface of the ground, the inclination of each branch being calculated at 1 in 30.

Sometimes the drain is carried through the scullery wall and terminated under the sinkstone, thus making a direct communication between the interior of the house and the drain, whereby the foul gases of the drains and sewers are invited into the house; for although a trap may be placed on the end of such a branch drain, it will not at all times prevent the foul air coming through it into the scullery, and thence probably into the house. It is very much better to terminate the drain outside the wall, and place a trap upon it there, and to discharge the sinkstone-water into that trap, so that at those times when the foul air of the drains may escape at that point they do so in the open air, and are there less injurious than when they escape into the house. Very little better than none is (or rather was, for people now see the fallacy of it) a "bell trap" at the mouth of a pipe in a sinkstone, the other end being inserted into the drain. These traps act as traps only when the cover is in its place (and very imperfectly even then), and they

so frequently become choked with tea-leaves and grease, that a remedy for this is often found in throwing away the cover altogether and leaving the end of the pipe open.

As to the kind of trap to be placed outside the wall to receive the sinkstone-water, and also for the yard gulley, to receive the surface-drainage, there are several kinds in common use.

Iron box-traps are neat in appearance, but they are objectionable, inasmuch as that, unless very well and carefully set, the foul air of the drain comes up through openings left round them between the trap and the setting—usually a few bricks in mortar or cement: but when properly and closely set they answer very well.

The earthenware trap is much better in this respect. The spout projects into the socket of the last drain-pipe, and it is easier in this case to make the joint air-tight. These traps, or yard galleys, are, however, often made too deep—to hold too much. The less space there is for lodgment of solid matter in a trap the better. The only excuse for making a space larger than is necessary to form the water-trap is that it requires cleaning out so much the less often; but this is of itself an objection. While the matter lies there it is decaying and giving off foul gases, and it is better that it should go to the soil as quickly as possible than that it should be retained (undeodorised and not disinfected) in traps for any considerable time.

The same kind of trap serves for the two positions named, and in many situations the same trap serves for both purposes, when the surface channel of the

paving of the yard is laid so as to allow the surface-water to drain to the sinkstone-trap; but this is, in some situations, inconvenient, and then a gulley is required in another part of the yard also.

Another kind is the syphon-trap, but it is not suitable for a yard-gulley; its proper place is at an intermediate point on a long length of drain, where the sewage, arriving at it with considerable velocity, is wholly carried through the trap without the risk of lodgment of solid matter.

This kind of trap is sometimes made with a short vertical piece in the centre for the purpose of access in case of stoppage by sediment lodging in the hollow. This occurs when the quantity of water used is insufficient to carry forward the solid matter with the requisite velocity.

A new kind of trap, and a very good one, is that invented by Mr. Dean. The sewage falls into a box fitted into the earthenware case, and the solid matter is thus easily removed by taking out the box and emptying it.

Another kind of trap is that invented by Mr. Mansergh, C.E.

Of Mr. Banner's trap I have no experience: I hope the form of it will be modified from the representation I have seen.

The paving of the yard or back premises of a house, is an essential part of the drainage, and may be of stone flags, dust-brick, or asphalt.

Water-traps.—Whatever the form of a water-trap may be, it consists essentially of a vessel full of water, across which, from side to side, is placed a diaphragm;

the lower edge of which is horizontal and dips into the water. The extent of the dip seldom, if ever, exceeds 2 inches, and is more often 1 inch, and even sometimes less. The greater dip is intended to offer a complete obstruction to the passage of air from one side of the diaphragm to the other; but water absorbs gases, and in this way they pass through it under the diaphragm and escape on the other side; and it is now understood that no form of water-trap whatever prevents, at all times, the passage of gases through it. The times when it mostly fails to prevent their passage are when they are driven upwards from the drain towards its upper end where the trap is situated, and there attain an elastic force greater than the atmosphere on the other side of the trap, when the pressure acts mechanically to increase the quantity of air passing through the trap, which at those times is seen (when persons are sufficiently observant of these obscure but dangerous small things) to escape in bubbles; and it is now also well understood that means of escape for these foul gases from the drain into the atmosphere must be provided in front of the trap.

Nearly all inlets to drains at the ground-level are near the doors or windows of dwelling-houses, and therefore the foul gases should not be allowed to escape at those points, under our noses, as it were.

It is necessary to observe that sewage, immediately on its entry into a drain, begins to give off the gases of decomposition, and continues to do so until it is buried in the soil at the outfall.

These gases are declared by the medical officers to be highly injurious to health. It may be, some of

them say, that the gases themselves are not injurious to health, but only offensive to the senses, and that it is the specific germs of disease which they convey which are to be feared; but they say again, in explanation, that even if the gases be not injurious of themselves they become practically so by acting as the carriers of the germs which are so, and therefore are to be prevented coming into dwelling-houses.

If a water-closet is to be connected with the house drain the form of trap belonging to it will be different from those already mentioned, and will depend upon the kind of closet apparatus adopted, the simplest kind being an earthenware pan with a trap of the kind called the syphon-bend, or **S** pipe, into the upper end of which the neck of the pan is inserted, and the lower end of the trap is inserted into the socket of the last pipe of the branch drain, in the same manner as the spout of the yard gulley already described.

Water-closets.—Many of these pans and traps have been fixed without any water supply from cisterns and pipes, and in some places with very good results, being kept clean by throwing down them the contents of the slop-pail, and in addition to that several pailsfull of water daily as a part of the regular household duty.

The shape of these pans is often objectionable, the neck being made directly under and concentrical with the rim.

There is a shape in which the back of the pan is vertical, the contraction from the rim to the neck being managed in the front and sides of the pan.

These are more easily kept clean. The pan and trap should be well supported, and firmly bedded on

concrete or brickwork, and the joints made perfectly air-tight. In converting a common privy and cesspool into a watercloset, the cesspool is sometimes merely filled up with earth and the pan and trap set upon that; but the settlement that takes place disturbs the joints and lets the foul air of the drain escape through them into the closet.

There are several kinds of water-closet apparatus of a more complicated kind, with various forms of traps. The worst kind is the pan-closet, in which a tinned iron or copper "pan" works in an iron "receiver." The receiver is a cast-iron box, large enough to allow of the motion of the hinged pan, and therefore of considerable size. The interior of the receiver soon becomes coated with the soil discharged into it from the pan, and is a permanent cause of offensive smell in the closet; for a quantity of the foul air in the receiver is drawn out of it every time the closet is used, equal in volume to the contents of the pan; the action being one of those everyday things which illustrate one of the principles of physical science—that two bodies, as water and air, cannot occupy the same space at the same time. This is the kind of closet apparatus usually recommended by plumbers who have not had much experience in these things; and therefore it is necessary that owners and occupiers of houses should enquire for themselves into the action and the merits of these and other things with which dwelling-houses are furnished by plumbers and other tradesmen, who, in some branches of their business, are, no doubt, good enough workmen, and understand what they do in those branches, but who, as a rule, certainly know

very little indeed about the proper construction of water-closets and their appendages of cisterns, pipes, and valves,—judging from what we too often see in houses in small towns.

The motion of the pan, swinging backwards and forwards in the receiver, disturbs the equilibrium between the air-pressure in the receiver and the outside, causing at times a partial vacuum and at other times a plenum of air in the receiver. To remedy this a hole is made in the cover, or somewhere near the top of the receiver, through which the foul air is driven on the descent of the pan, and through which air is drawn into the receiver on the ascent of the pan to its position of rest; thus a constant pumping of foul air out of the receiver into the closet goes on, unless the further remedy be adopted of attaching a pipe to this hole in the cover of the receiver and leading its other end through the wall into the outer air; and the effect of this is usually spoiled by making the pipe too small in proportion to its length, and too tortuous in its course, so that the obstruction caused by the friction due to the velocity with which the air must pass through so small a pipe is sufficient to prevent the intended motion; for it must be observed that the operation is performed quickly, and therefore through a small pipe the air must pass with great velocity; but obstruction to the motion of air caused by friction against the sides of a pipe increases as the square of the velocity, divided by the diameter of the pipe, so that whatever the obstruction to a given volume of air passing through a given length of 2 in. pipe in a given time might be, it would be thirty-two

times as much through a 1 in. pipe of the same length.

But the usual way with plumbers is to attach a very small pipe, whereby they defeat the object in view, and instead of the foul air being driven by force through this small pipe it prefers the easier passage through the opening of the basin into the apartment. This is indeed one of those things in which a small meddling is worse than doing nothing, for to make such a thing answer the end sought it must be done thoroughly and on scientific principles; not on that account necessarily more costly, be it remarked, but, on the other hand, probably much less so.

As the pan-closet is the worst form, so the best is that kind which is wholly of earthenware and has a plug valve, the motion of which is vertical and direct, and is situated at the side of the basin.

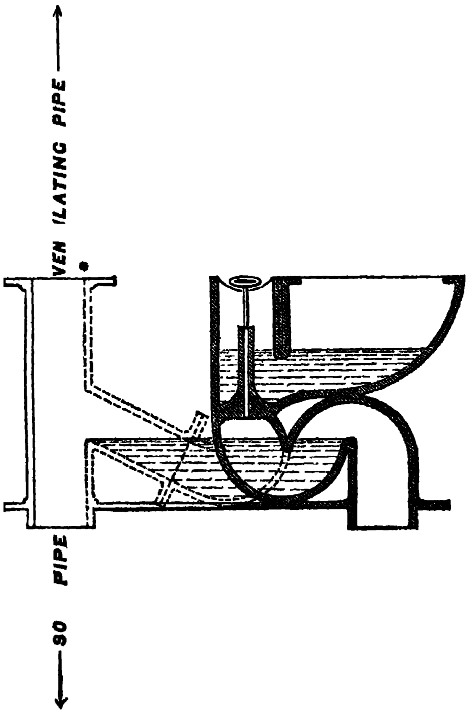
I have always considered this kind of basin the best I have known, with its plug-valve and direct pull, the outlet being on one side of the basin. Fig. 27 shows Mr. Jennings's arrangement.

I think, however, that it would be an improvement to turn the trap-bend round in the opposite direction, as shown by the dotted lines in the figure, so that a vertical ventilating pipe may be attached to the top of the soil-pipe.

One of the commonest errors of plumbers, in fitting up water-closets, is to make the down-pipe from the cistern to the basin too small. There is little or no excuse for this. The length is in no case great, and therefore the difference in the cost (which is the only conceivable reason for doing it) can in no case be of

much account; but the difference in the effect produced is very great. What is wanted for this purpose is a sudden flush of water, not necessarily greater in quantity, but of quicker action; and this is impossible

Fig. 27.



when the down-pipe is so small as many are. It should be a rule that this pipe should be 1¼ in. diameter. The lightest pipe made is sufficiently strong for the purpose, and any saving that may be desired should be sought for in thickness of metal, and

not in size of pipe. Nine pounds weight per yard is quite sufficient for a pipe of $1\frac{1}{4}$ in. diameter.

Whatever the form of closet apparatus, the one feature common to them all is the soil-pipe. This is the pipe which intervenes between the trap of the closet-basin and the drain, and the top of it is usually the highest point of the house-drainage, and therefore is the point at which the gases arising from the decomposition of the sewage have the greatest tendency to accumulate,—all those, that is to say, which are of less specific gravity than the atmospheric air. It is impossible, except by means of an expensive application of antiseptics, to prevent the liberation of the gases of decomposition of sewage (which begin, as has been already said, as soon as the sewage is formed, and continue until it is finally disposed of at the outfall) and it is quite as impossible to prevent their escape into the atmosphere. The only practicable thing that can be done to prevent injury from them is to conduct them to places out of reach of the air we breathe continually,—that is to say, into the atmosphere above our heads, such of them, at least, as are of less specific gravity than the atmospheric air at the moments of action, and these gases are the most injurious because the most volatile. The diffusion of the heavy carbonic acid gas is slower, and it is not so important a vehicle of conveyance of germs of disease as the lighter gases are.

Of the evil effects of the gases of decomposing sewage, Dr. George Wilson, in his "Handbook of Hygiene," says, after enumerating some cases where enteric or typhoid fever had taken place from the

entry of these gases into places where people had to breathe them, "While numerous other instances are recorded of the evil effects of the air of sewers, cesspits, drains, &c., in producing temporary ailments, such as nausea, vomiting, diarrhœa, and headache, the great interest which attaches to this important subject rests on the development and spread of enteric fever;" and that "the sewer air, laden with the specific poison, readily finds its way into houses on account of its greater tension, and in consequence of badly trapped and imperfectly ventilated drains."

Ventilation of House-drains and Sewers.—The ventilation of sewers and house-drains has received a good deal of attention, and many propositions have been made which will occur to those conversant with the subject, but which need not be repeated here. No method of ventilation, however, is at once so simple, practical, effective, and inexpensive as open communications between the drains and sewers and the atmospheric air. When openings are made into sewers or drains, the gases of decomposition, previously accumulating under pressure, escape freely into the atmosphere; and the mischief is that when they escape at the ground-level we must breathe them. But there is no necessity for this; they can be conducted up into the atmosphere above the house-tops, if the pipes be sufficiently large and sufficiently numerous. These two requirements may be at once stated, from experience, to be, that the ventilating pipes should be 4 inches diameter, and that there should be at least one to every house-drain.

The retail prices of iron pipes suitable for drain-ventilation are as follow:—

3 in.	diameter,	3s. 3d.	per 6 ft. length.
3½ in.	"	3s. 10d.	"
4 in.	"	4s. 8d.	"
4½ in.	"	6s.	"

The mischief done by some plumbers in this matter is very great, for when they can be brought to see that ventilation of house-drains is necessary at all, they recommend to their employers a small lead pipe, say ¾-in. or 1-in. diameter. They wholly overlook the element of friction through so small and so long a pipe, which is of itself sufficient to prevent the pipe being of any use. If no motion were to take place through the pipe, no pipe would be required at all; and it is this necessary element of motion of the foul air through the pipe that plumbers overlook. And, sometimes, to the inefficiency of a small pipe they add the obstruction of bends in it, and when such a pipe has been found by experience to be useless in preventing foul gases coming into a house, ventilation is thought to be useless, whereas it is the plumber who is in fault.

Now a plumber, unless he is in a more than usually large way of business, does not keep in stock the thin cast-iron rain-water piping which is most suitable for ventilating pipes,—he has to get it from the ironmonger: this is out of his usual course of business, and he recommends a lead pipe; but, as a lead pipe of sufficient diameter would be too expensive, he pretends that a small pipe is sufficient.

In reality he does not take the trouble to think what

size the pipe ought to be, and it appears to him that the size of the pipe is immaterial.

The owner of the house is glad to hear from the plumber that a small pipe will be sufficient; he would be still more pleased if he could be assured that none at all is required.

One of the last ventilating-pipes of several thousands erected under my directions before this present writing is 4½ inches diameter; and when the workmen had finished all but putting down the last trap at the ground level, they put into the drain a bit of white paper, and it was at once carried up the ventilating-pipe and was seen to fly out of the top of it.

When I constructed the sewerage and drainage of the town of Leek, I caused to be erected a number of ventilating pipes at the upper ends of the house-drains. Since that time the Sanitary Inspector has been requested by the Improvement Commissioners to report to them the state of the ventilation of the sewers and drains of the town, and the following is a copy of his report.

"The public sewers and private house-drains connected therewith are ventilated by means of 1,194 metal pipes, varying from 2½ in. to 4 in. diameter, carried up the exterior walls of buildings above the levels of windows. Although means of ventilation are much required in places, it may be said, in general, that the provision made for the ventilation of sewers and drains is much more adequate than was anticipated.

"Notwithstanding the fact that little was said as to the importance of sewer and drain ventilation when

these works were constructed, the engineer who constructed them appears to have devoted considerable attention to the subject; and, at a subsequent period, upon the recommendation of the Sanitary Committee, the Board made an order that every drain and branch-drain hereafter constructed be ventilated at its head by means of a pipe or flue, terminating above the windows of the house or building.

"The propriety of thus dealing with the subject has been so often demonstrated in Leek, that I only need refer to the fact that where the necessity of sewer and drain ventilation has been altogether ignored, typhoid fever has been most prevalent. After careful inspection and consideration, I cannot recommend any other method of dealing with the subject than that already adopted by the Board. The principle inculcated by the order now upon the books is that it shall not be possible for foul stagnant gas to be present in any sewer or house-drain. The means determined upon by the Board for that purpose are extremely simple, easy of application, and strictly in accordance with natural law.

"It has repeatedly been proved here that the best water-trap at a drain-head (especially if it be inside a house) without proper provision for ventilation, is a snare and a delusion, fraught with much hidden danger to health and life. I therefore submit that the Board cannot do better than carry out in its integrity the principle of ventilation already adopted, by requiring a sufficient number of outlets at the head of each sewer and drain; thereby allowing nature to establish a natural circulation by which continuous diffusion,

dilution, and rapid oxidation, will at least reduce the danger to a decimal degree."

1 have been informed by the Sanitary Inspector, Mr. Robert Farrow, that he has frequently held a candle or a few lighted shavings to an untrapped gully in the street, and has found the current of air to be inwards. From that it may be inferred that the tall ventilating pipes are fed with atmospheric air, through any defective trap there may happen to be at the ground level, and so the sewers and drains become supplied with currents of atmospheric air, preventing the formation of sewage gases, to some extent, and carrying off those which are formed.

Dr. Alfred Carpenter, in a paper read at a meeting of the Health Department of the Social Science Congress in 1869, on the "Influence of sewer gas on the public health," said, speaking of Croydon, "When a stink is perceived at a particular spot, or in a particular house, orders are generally given to stop the place of issue by trapping the offending opening, with the beneficial result of removing the smell and staying the progress of disease in that particular house or place; but no means are taken to prevent its influence being felt elsewhere. The mischief is simply transferred in a selfish kind of way, and the public suffer for it. I have had much experience of this kind of thing in our district, and soon saw that trapping was not a proper remedy unless it was accompanied by the provision of another exit in a safer situation."

Further, that "The Croydon Local Board determined, three years ago, to adopt the principle of opening the extremity of every sewer, and of every

branch or house-drain in connection with the sewer, and make every house ventilate its own house drain. The Local Board also had openings made into the sewers at 100 yards interval, so as to allow of a constant and continuous current of air. By these means the effects of sewer gas have been entirely obviated, and the consequences removed, in those portions of our district to which the law is made to apply, in a most marked and decisive manner." . . . . "The sewer gas will form, at times, very abundantly in the house-drains,—the houses being, like gas-receivers, open at the bottom only, the sewer products will make their way through the traps into such houses; and if the traps become, as is often the case, untrapped, especially in dry weather, there is a ready means for the entrance of the gas into the house, independently of the means afforded by the water in the trap itself, which is a ready conductor of the miasms,—absorbing the agent on one side and giving it off on the other."

After pointing out that the formation of sewage gas cannot be prevented, and that trapping is only stopping the danger at one point and forcing it in another, quite as perilous to those exposed to its influences, Dr. Carpenter said, "Whilst, therefore, these gases will form, how can we best avoid their influences? The nature of sewer gas has been well pointed out by various chemists and medical authorities,—all concur in the belief that dilution destroys it; that if sufficiently diluted with air it becomes innocuous, and its sting is taken away. When it first escapes from a sewer it carries with it some condition which is injurious to life, tending to prevent some necessary

change in the blood, or other vital tissues, either by its own power or by means of a property to which it simply bears the relation of carrier. If it be mixed with sufficient air, especially if that air be ozonised, the miasm becomes oxidized and comparatively harmless, or if not so oxidized its presence is not injurious to life." Speaking of the motion of air in sewers and drains being upwards, he said, "Our problem, therefore, is how to render this circulation positively continuous. This has been effected most perfectly in our district by compelling every new house to have ventilation for itself. The soil pipe is continued upwards in a straight line above the level of the pan (of the water-closet), between the trap and the sewer, and it is made to terminate by an open extremity above the eaves of the house, away from the window, and not close to, or on a level with, the chimney. Every connection with a sewer requiring the presence of a trap, has that trap guarded from the consequences of pressure by a ventilator similar to that of the soil pipe, the latter being placed as close to the trap as possible. It is found necessary to make these shafts ascend straight up, and not curve or turn at right angles, or their efficiency is interfered with. The result of making these innumerable openings at the higher points of the sewer has been to promote a rapid circulation through the sewer, by which all sewer gas is removed as quickly as formed, and no concentration can take place."

Dr. Thursfield, in his Sanitary Report on the Borough of Shrewsbury, March, 1875, says: "The object in ventilating a soil-pipe is to afford such free exit to

the gas that it shall neither pass through the water in the trap, nor through any corrosion or leakage in the soil-pipe itself. The mode in which soil-pipes are ordinarily ventilated does not accomplish this; a pipe of small calibre is carried from the soil-pipe with many turns and twists to the top of the house, and the retardation to the up-draught, caused by the small calibre and length of the pipe, is so great that in many cases it practically does not act at all."

Fluctuation of the volume of sewage.—It is well known to those who have had to do with sewers that the volume of sewage varies from hour to hour of the day; and this takes place to such an extent that one half of the sewage due to the whole 24 hours often flows off in six or eight hours, and that circumstance has to be taken into consideration in determining the size and other conditions of a sewer. This fluctuation is caused by the varying quantities of water used in houses at different hours of the day. Repeated gaugings of the flow of sewage in dry weather, when the quantity is not influenced by rainfall, but is chiefly that used in houses, has shown that the maximum flow during some one hour of the day is about twice as much as the minimum flow during another hour of the consecutive 24 hours.

Mr. Marten has stated that at Wolverhampton about three-fourths of the daily supply of water was given between the hours of eight in the morning and eight in the evening.

Mr. Hawksley has stated that at Salford, in the year 1862, the draught of water between eight a.m. and noon was from 2 to 2½ times the average quantity of

the whole day, and that in the night it was not more than $\frac{1}{4}$ of the average quantity.

A day's observation of the state of the chief service reservoir of the Manchester Water Works in 1864 showed the quantities flowing out to be

from	9 a.m. to noon	$1\frac{1}{2}$	million	gallons
,,	noon to 3 p.m.	$1\frac{1}{2}$	,,	,,
,,	3 p.m. to 9 p.m.	2	,,	,,
,,	9 p.m. to 9 a.m.	2	,,	,,
		7	,,	,,

So that during the six hours from 9 a.m. to 3 p.m. the average hourly quantity going out of the reservoir was $\frac{1}{14}$ of the whole quantity during the 24 hours, or 500,000 gallons; from 3 p.m. to 9 p.m. $\frac{1}{21}$, or 333,333 gallons; and from 9 p.m. to 9 a.m. $\frac{1}{42}$, or 166,666 gallons; the first-named hourly quantity being three times that of the average hourly night-flow. The fluctuation of the water-supply is, as might be presumed, greater than that of the sewage flow, because there is always some ground-water running in the sewers, which seems to make the night flow of the sewers about half as much as the maximum daily flow.

In several towns the maximum hourly quantity of dry weather sewage flowing at the outfalls of the sewers has been found to be a little more than twice as much as the minimum.

Such observations show that the fluctuation of the volume of sewage is very considerable even in dry weather; and another cause of fluctuation is the rain-

fall. Everybody knows that immediately after a shower of rain "the drains smell." The foul gases of the drains are, in fact, then forced out by the influx of water. When the water in the sewer is rising, it compresses the air in the sewer above it, when it is confined, and, reacting, as all elastic bodies do, with a force equal to that with which they are compressed, the sewer air forces its way into the houses through kitchen sinks, traps, and water-closets, and through street gulleys, and other places at which it ought not to be allowed to escape.

Open and close sewers.—When a close sewer is broken into the escape of the pent-up gases is fearful in volume and malignity, and the death of workmen has frequently occurred when this has been done, and more frequently has illness of many people arisen from it.

When a sufficient number of openings has been made through which there is free communication between the atmosphere and the interior of the sewers the escape of sewer gas at any one opening is almost imperceptible. Now if we consider the bearing of these facts we shall see that open and not close sewers are to be preferred.

But wholly open sewers in populous places cause too much inconvenience, and therefore for the sake of convenience sewers in populous places must be covered. Between these two antagonistic requirements we must take a middle course, and, while covering the sewer, must make frequent openings through which a communication may take place between the interior of the

sewer and the atmosphere, the openings being covered by gratings at the surface of the ground.

On main sewers Mr. Rawlinson advises that the openings be not more than 100 yds. apart; but it is evident that the greater the number of openings the better, and it is only a question of expense whether the whole length of every sewer should not be open to the atmosphere, the grating covering the opening being continuous. The objection raised on the question of expense is of course a valid one in a degree, and in the case of deep sewers must be met by substituting openings at intervals; but the nearer sewers approach to open channels the better. House drains, however, should be covered, and the communication should be made between the drain and the atmosphere above the roof by means of a vertical pipe, as before mentioned, and also at the upper ends of street sewers, where the ground is steep; but in the greater portion of the sewers, and especially in the lower parts, the openings should be at the ground level.

As has been said, sewers or at least pipe sewers, should be laid in straight lines. Besides other advantages which this method has over curves, it allows the sewers to be readily examined, without breaking up the roads, for, by carrying up a man-hole at one bend, and an opening at each of those next it, in front and rear, down which a lamp may be lowered to the sewer, it may be seen from the man-hole if the sewer be open.

In well-arranged sewers, stoppages may be almost certainly prevented; nevertheless, the original design (due, I believe, to Mr. Rawlinson) should be adhered to, for, even though such examinations need seldom

be made, the numerous communications thus made between the sewers and the atmosphere are very beneficial, if the covers of the man-holes and the lamp-holes be made with openings, or if they be covered with gratings. They then act beneficially by admitting fresh air to the sewers, providing an efficient system of ventilation, such as has already been mentioned, be adopted in connection with these openings.

The man-holes should be about 3 ft. square, gathered in near the top an inch or so each course until the opening is reduced to the length of 2½ bricks, and the width to 2 bricks. Upon the brick walls a cast-iron frame is set, within which a moveable cover is fitted, the construction of which should be such as to be as open as possible, consistently with safety to horses' feet.

The bottom of the man-hole should be formed so as to prevent lodgment of sewage, and should be of the form of the lower half of the adjoining pipes, or of the invert of the sewer, when of brickwork.

The lamp-holes may be vertical pipes, set up on a square junction, and carried to within about a foot of the surface. Round the mouth of the vertical pipe a small bed of concrete should be laid to receive the pressure of the traffic over the cover, which should be supported upon two courses of brickwork, bedded upon the concrete, so that weights passing along the roadway shall not be transmitted to the pipes. The cover should be of cast-iron, similar to that of the man-holes, but need not be so large. In macadamised roads, the iron covers of both should be surrounded by pitched stone for the distance of a yard or so.

Road drains.—Wherever there is a considerable number of houses together it will be advisable to lay a common sewer into which they may be drained, so that the sewage may be conveyed to one spot and disposed of.

Now, wherever there is a considerable number of houses together there is usually a road drain, or culvert, or several of them, for the purpose of carrying off the rainwater. These may have their outlets as it may be; but it may be taken generally that they are sufficient for the purpose for which they were laid down, but for that only. To convert these into sewers is quite a wrong proceeding. We find, indeed, as matters of fact, that in many cases house sewage is turned into these road drains and culverts, but we find also the necessary consequences—stoppages, and nuisances arising from the breaking out of their contents. Before such pipes as are suitable for sewers and house drains were made, road drains were chiefly formed of bricks, sometimes with mortar and sometimes laid dry, or of rough stonework, and it is chiefly such drains and culverts as these that we find in existence, and in some cases receiving part of the house drainage. They are often of considerable size, and on that account are sometimes thought to be sufficient for both road drainage and house drainage, and so far as size and fall go they might be so in most cases, but the chief consideration is that house sewage must be cleansed (I prefer to say cleansed rather than purified) before its escape into a river or stream, and if it be mixed with a large quantity of rainwater—which it would be if put into road drains—

the cost of dealing with it is greatly increased, while the rainwater itself, if unmixed with house sewage, might flow in its natural courses.

When the method of purification is that of the irrigation of land, a certain quantity of rainwater is sometimes useful in helping to float the sewage over a sufficient area to effect its purification, but this does not tell against the main argument—that the bulk of the rainfall should be allowed to flow off by the channels which have hitherto conveyed it, and that sewers should be laid to convey the sewage and a limited quantity of rainwater to the outfall; and under these circumstances the sewers may be of smaller size than would be otherwise necessary.

But it is not so much that the quantity of rainwater in a year would be difficult to deal with, if its flow were at all regular, day by day, as that it is difficult to make any effectual provision for the occasionally sudden and excessive flow.

The roughness of the interior of these road drains and culverts prevents the sewage flowing freely off, and causes a generally foul state of the bottom, and this is increased by the escape of the liquids through the joints of the brickwork or stonework, for they are not impermeable, which is an essential requisite in the lower half of the sewer.

In the definition clause of the Act, "drains vested in or under the control of any authority having the management of roads, and not being a local authority under this Act," are excepted from the definition of the word *sewer*.

Circular sewers.—When the situation of the upper end of a sewer is such that it cannot be extended so as to include the drainage of any additional number of houses, the upper end of the sewer may be of 6-in. pipes,—for what length downwards will depend upon the fall, but the length will in most cases be comparatively short. Below these short lengths of dead ends 9-in. pipes may be continued for considerable distances, which may, when necessary, be succeeded by 12-in. and 15-in. pipes, for distances still greater; but when it becomes necessary to make the diameter as much as 18 in. it will in general be better to lay a brick sewer, with a half-brick ring; and half-brick, or about 4½ in., is a sufficient thickness for diameters up to about 2 ft. 6 in. Sewer bricks should in all cases be moulded thin on the face and thick at the back, and more or less so according to the radius of the sewer, so that they may be bedded solidly upon each other throughout the width of the bed. For sewers of larger size, and up to 3 ft. 3 in., or 3 ft. 6 in. diameter, the bricks may be moulded of the dimensions of 9 in. long, 6 in. wide, and of a thickness of 2¼ in. on the face, and 3 in. at the back. Although heavier than bricks of ordinary size, these are not inconveniently heavy in the handling, and about the same cubical quantity of work per day is done with them as with bricks of ordinary size. I used bricks of these dimensions, moulded for the purpose, in the north outfall sewer of the Leek Drainage. Its diameter is 3 ft. 3 in. If the diameter be required to be greater than about 3 ft. 6 in., the thickness should be 9 in., or one brick, up to, but not

much exceeding, a diameter of 4 ft. 6 in., or 6 ft. high and 4 ft. wide.

Egg-shape sewers.—For the purpose of concentrating a small flow of sewage, and so increasing its depth and consequent velocity, the bottom of a brick sewer is sometimes made of smaller radius than the top, and the usual ratio of height to width is three to two. It is evident that a given small quantity of sewage flowing in a circular sewer spreads out over the bottom and reduces the hydraulic depth, and where the inclination of the sewer is small and the variation of the quantity is great this form is preferable to the circular form; otherwise it is not so.

The circular form has many practical advantages which the egg-shape has not. It is stronger; the fluctuation of the height of the surface of the sewage-flow is less, and for this reason the extent of surface exposed to wet and dry on the sides of the sewer is less, which is in its favour, for the grease and other matter left on the inside of the sewer at and near the surface of the sewage-flow gives off gases of decomposition, and the more so in proportion to the extent of surface exposed.

Sewer bricks.—The bricks of the invert or lower portion of a sewer should be of very good quality. They are subject to constant abrasion by hard matter; and the joints should be of cement, or of ground hydraulic lime used in the manner of cement, with an admixture of not more than two of sand to one of cement, or lime, the sand being clean and sharp to the touch. The blue bricks made in Staffordshire and Shropshire are excellent for sewer work, and the gault bricks in

the neighbourhood of London; but as the bricks of the locality will probably in most cases be used for sewers, care should be taken to select the best kind of clay the locality affords, within reasonable distance, and to have the bricks well burnt.

It has occurred in sewers that the bottom has been deeply cut into by the action of sand and other solid matter upon it for a number of years.

Depths of sewers.—As to the depth at which sewers should be laid, that depends altogether upon local circumstances. Where the surface of the ground is generally of uneven height, the level of the lowest part of the opposite houses is the guide, the middle of the height of the sewer being not less than 2 ft. lower than such lowest points. In such ground, taking this minimum depth at several points along the course of a sewer, or along some considerable portion of its length, the proper inclination may be ascertained, and the depth at every part of the course. The proper gradient being determined, the easiest way of ensuring its exact formation is to place two fixed sight-rails across the line of trench at an equal height above the intended bottom of the sewer, and to use a moveable rod, with a cross-head upon it, to bone in every part of the bottom truly. This is a much better way than driving ahead with a straight-edge and hand level, although this method is adopted for the short lengths of house drains.

Junction of house drains with brick sewers.—The junctions of the house drains with a sewer are sometimes made to enter it at the bottom, below the surface of the ordinary sewage-flow, but this cannot

be commended. The intention probably is to prevent the sewer gas passing up the drains to the houses, but although this method has that effect there are practical objections to it, based on experience of the silting up of the lower ends of the drains when this method has been adopted; and, naturally, the velocity of the sewage-flow is checked whenever the sewage rises in the sewer. The preference for this method has been excused on these grounds. All sewage matter, it is said, is soluble in water, if a sufficient length of time is given to it, and with that view the size of the house drain is made rather larger and the velocity of the sewage-flow is considered as a secondary question. So that all be dissolved, it is supposed that a lesser velocity is necessary, but this can hardly be a practical way of looking at the thing. It is impossible to avoid the entry of all insoluble matter into a house drain, and when the junction with the sewer is made in this manner it is only a question of time when the lower end of it will be found silted up. The best point in the height of a brick sewer at which to make the junction of a house drain is at the haunch of the arch, or just above the springing. The passage of sewer gas up the drains must be got rid of by a proper system of ventilation at the upper ends of the drains. Taking the point above mentioned in the height of a brick sewer to be the proper one, a junction block, formed obliquely, should be set in the brickwork wherever a house drain is, or may be required to be, connected with the sewer. "Oblique junction blocks" are quite old things now. One of these being built into the brickwork, a bend pipe is to

be inserted to give the lead of the house drain the proper direction. Their prices are about as follow, for 4½-in. and 9-in. brickwork respectively, viz., for 6-in. pipes, 3*s*. 9*d*. and 5*s*. 6*d*.; for 9-in. pipes, 5*s*. 6*d*. and 7*s*.; for 12-in. pipes, 8*s*. and 10*s*. 6*d*. each.

Sewer invert blocks.—For egg-shaped sewers the stoneware invert blocks are useful and give facility in the execution of the work. They are made for 4½-in., 6-in., and 9-in. brickwork, and their prices per lineal foot are about as follow, viz., for 4½-in. brickwork, 1*s*. 2*d*.; for 6-in. brickwork, 1*s*. 8*d*.; and for 9-in. brickwork, from 2*s*. 2*d*. to 3*s*. 6*d*., according to the width.

§ X.—ARRANGEMENT OF THE OUT-BUILDINGS OF SMALL HOUSES.

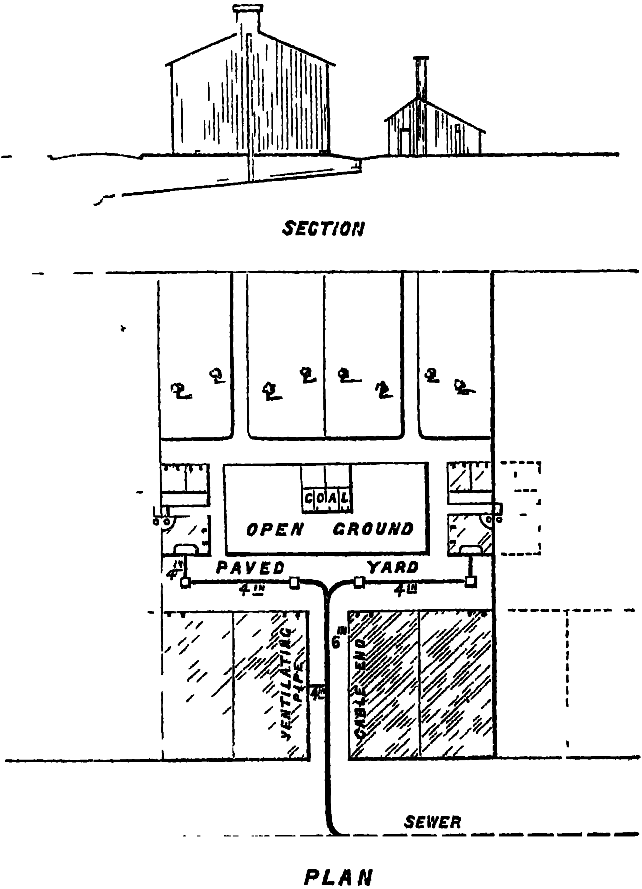
Those who intend to build houses mostly have them built according to their own arrangement and fancy; and this must be so; and I offer the following remarks only as a suggestion, but one which is founded on an experience of different arrangements, some of which, though not any less expensive, are less conducive to the convenience and health of the tenants than the one shown in the accompanying sketch.

For instance, there may be a row of houses with an entry between each two of four, and opposite the entry a common washhouse for the four houses. There can hardly be a worse arrangement. When there is a common yard to several houses it is of practical importance that the outbuildings be so arranged as to prevent, as far as circumstances make possible, a concentration of the work to be done, or rather a congregation of persons, on one spot for the performance of any office; as, for instance, for washing. It is too much to expect that four women should amicably arrange their washing days so that one washhouse shall serve for [illegible] two may so agree. The arrangement [illegible] sketch is not an invention or design of [illegible] which I have found to be better than [illegible] mentioned.

As to the [illegible] is better on all grounds that there should be a separate one to each house, as

indicated in the sketch, but one cesspit for the two does well enough.

Fig. 28

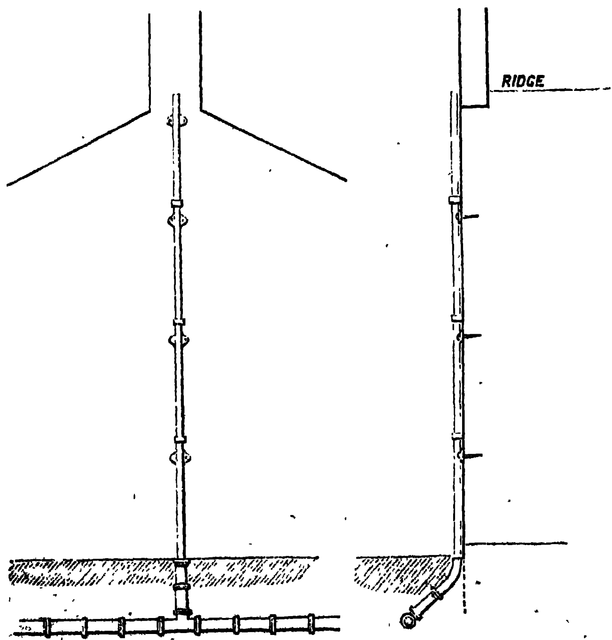


This is, as shown, between the privy building and

the washhouse, and one roof covers all—washhouse, privies, and cesspit. The ends of the space occupied by the cesspit are left open. The ashes of the house-fires may be thrown into this place, or there may be a separate ashpit for dry ashes, as shown at the back of the coal-sheds.

Each washhouse has a boiler, and every two adjoining washhouses have a common chimney, and as

Fig. 29.



it adjoins the two cesspits it may be made to ventilate them by leaving a half-brick hole on each side. This is not essential. Sufficient ventilation is afforded by

leaving the two ends open, as before described. In each washhouse is a sinkstone, under the window, and the waste pipe from the sinkstone passes under the paving of the yard and empties into the trap opposite, which is set low for this purpose, into which also the house slops are thrown. A trap is arranged conveniently near the door of each house, for when there is no such convenient place near the door the slops are thrown anywhere. These are but trivial things, in one sense, but in the aggregate they are of much importance. The central open space shown in the sketch gives room for the children to play in.

§ XI.—PAVING MATERIALS.

The paving of the surface of back yards, and of all spaces extending for some distance from the thresholds of house doors, is an essential part of house drainage. Without it a house cannot be kept clean, as we have said in another place. Without paving, the surface of the ground is worn into holes, which are puddle-holes in wet weather, and at all times an unpaved surface near the common door of a house is necessarily in a dirty condition.

After the house drain has been properly laid there is no need to again disturb the surface, and in that case it may be asphalted, at a cost of from 1*s.* 6*d.* to 2*s.* per square yard; but of course something more is necessary than to mix gas-tar and gravel together and lay it down, as is sometimes done, and called asphalte. The pitch of gas-tar should be procured, and remelted, and a portion of the oil which had been extracted for chemical purposes should be added to the melted pitch. After the naphtha has been taken out of gas-tar there remains a residue, out of which an oil—commonly called creosote oil, although proper creosote is distilled from wood-tar—is extracted, and is used with melted pitch to bring it back in some degree to a state of tar. The boiler or pan in which the pitch is melted should be fitted with a tap, through which the liquid contents may be drawn. First, put into the boiler 1 gallon of the creosote oil to 1 cwt. of

pitch; boil them; add more oil, up to 1½ or 2 gallons to the cwt. of pitch, as required. Draw off a small quantity into cold water from time to time and try its stiffness by dipping a straw or stick into it, and make it so that it will barely run down the stick; or touch it with the finger, and if, on slowly withdrawing the finger, it adheres and follows it in a string, it is of the proper consistency. Boil well and mix thoroughly. Let the foundation upon which the asphalte is to be laid be free from dirt. If gravel be the material used let it be first dried, and then pass it through a screen of 1½-in. mesh, then through another of ⅝-in. mesh, and then take out the sand through ¼-inch mesh; the coarse stuff to be laid in the bottom. Engine cinders are a good material. Pass them through a 2-in. screen; break the coarse lumps for the bottom; screen the middle stuff again for the top through ½-in. mesh. For footpaths or yard paving, 1½ to 2-in. is a sufficient thickness; for roads, 3 to 3½-in. Roll each coat well with a 6 or 7-cwt. roller; or better, 10 cwt. Where a number of surfaces about houses are to be paved at once, there need be no difficulty in finding the proper materials and the workmen to apply them.

The dark appearance of the asphalte can be relieved by sprinkling over it the siftings of clean gravel, clean and dry quarry rubbish, the red ashes of engine furnaces, or, best of all, crushed spar from limestone quarries.

Portland cement may be used for the paving of yard surfaces, where gravel is plentiful, in the following manner:—

Let the ground be removed to a depth of 3½ inches.

Mix, then, clean coarse river gravel with ground hydraulic lime, or cement, in the proportion of 1 of lime or cement to 6 of gravel, and lay this down of a thickness of 2 inches. Screened gravel is then to be mixed with Portland cement, in the proportion of 2 of cement to 5 of gravel. This is to be deposited upon the previous layer before the lime has had time to set. The surface of this second layer is to be then grouted with neat cement until a fair face is produced, with flatting tools. Upon the neat cement clean sharp sand is to be spread and beaten into it. The cost of this, where gravel is plentiful, is 2*s.* 8*d.* per square yard.

The quality of the cement should be tested by making a bar of the neat cement an inch square and something more than a foot in length, and, giving the bar 1 ft. clear bearing, place a weight of 36 lbs. upon the centre of it. This can be done by anyone, anywhere, while the test by direct pull requires special apparatus.

Paving-bricks make good work, especially the dust bricks made in Staffordshire, and the burrs made in Shropshire. They should be bedded in cement, with which also the joints should be flushed.

Whatever the paving be constructed with, channel bricks should be laid to convey the house slops to the gulley or drain-trap.

Sandstone flags, such as are procured abundantly in Yorkshire, are perhaps the best paving materials, when squared down to a depth of 2 inches on the edges, and olidly bedded upon a foundation of clean cinders, avel, or brick rubbish, not less than 4 inches deep.

§ XII.—COMPOSITION OF SEWAGE.

Of the composition of sewage the Rivers Pollution Commissioners say, in their Report, dated February, 1870, "Sewage is a very complex liquid; a large proportion of its most offensive matters is, of course, human excrement, discharged from water-closets and privies, and also urine thrown down gully-holes; but, mixed with this, there is the water from kitchens, containing vegetable, animal, and other refuse, and that from wash-houses, containing soap and the animal matters from soiled linen. There is also the drainage from stables and cow-houses, and that from slaughter-houses, containing animal and vegetable offal. In cases where privies and cesspools are used instead of water-closets, or these are not connected with the sewers, there is still a large proportion of human refuse in the form of chamber slops and urine. In fact, sewage cannot be looked upon as composed solely of human excrement diluted with water, but as water polluted with a vast variety of matters; some held in suspension, some in solution."

In December, 1869, Mr. Edward Smith, F.C.S., read a paper before the Torquay Natural History Society, which he called "The Chemistry of Sewage" and in which he estimates the bulk of excreta at 10 cubic feet per annum per head of population, and its weight 630 lbs. The fæces form $\frac{1}{10}$ and the urine $\frac{9}{10}$ of

bulk, or 1 cubic foot fæces and 9 cubic feet urine per head per annum.

"Food is partly assimilated and partly excreted as urine and fæces. The urine consists of water holding in solution a highly nitrogenised body called urea, as well as sulphates and phosphates of soda and potash, and common salt. The fæces consist of those substances which have not been digested, such as disintegrated muscle, bone, or mucus, and those salts which are insoluble in water, viz., phosphate of lime and phosphate of magnesia. The urine yields—by drying or evaporation—about 4 per cent. of dry solids, and the fæces yield, by drying, about 25 per cent. of dry solids. Thus, speaking broadly, the mixed excreta contain urea, with phosphates and sulphates of soda, potash, lime, and magnesia. But the nitrogen of the urea is readily converted into ammonia, that is, into a compound of nitrogen and hydrogen, the ferment or active agent of the change being a peculiar nitrogenous substance always voided with the urine. Therefore we may put the available educts of excreta as ammonia, phosphoric acid, sulphuric acid, potash, soda, lime, magnesia. The human excreta simply represent the ingredients taken from the soil in the shape of wheat, potatoes, sheep, or oxen, and these alkaline phosphates and sulphates are as essential to the growth of vegetables as food is to man."

In Krepp's "Sewage Question" it is stated that the average of the estimates of Liebig, Lawes, Hofmann, Witt, Way, Thudichum, Boussingault, Stockhardt, Saussure, and others, is as follows :—

	Per day.	Per annum.	
Solids (about 1-10th of bulk) .	0·24 lbs.	87·60 lbs.	1·39 c. ft.
Fluids (about 9-10ths of bulk) .	1·95 lbs.	711·75 lbs.	11·29 c. ft.
	2·19 lbs.	799·35 lbs.	12·68 c. ft.

The four principally useful ingredients of an average individual are said to be—

	Fæces.	Urine.	Total.
Ammonia (nitrogen) . .	1·49 lbs.	9·38 lbs.	10·87 lbs.
Phosphate of lime (phosphoric acid).	2·00 lbs.	2·80 lbs.	4·80 lbs.
Potash	0·25 lbs.	1·08 lbs.	1·33 lbs.
Organic substances	10·51 lbs.	22·49 lbs.	33·00 lbs.
	14·25 lbs.	35.75 lbs.	50·00 lbs.

The solid and fluid excrement is thus again divided :—

	Fæces.	Urine.
	per cent.	per cent.
Water	75	93·99
Organic substances	12·20	4·15
Nitrogen*	1·40	1·42
Phosphoric acid †	1·06	0·24
Potash	0·29	0·20
Insoluble silica	1·48	
Oxide of iron	0·54	
Lime	1·72	
Magnesia	1·55	
Sulphuric acid	4·27	
Soda	0·31	
Chloride of sodium	0·18	

* Nitrogen equal to ammonia . . . . . Fæces 1·70
Urine 1·73

† Phosphoric acid equal to phosphate of lime . Fæces 2·30
Urine 0·52

From Dr. Letheby's "Notes and Chemical Analyses," reprinted from the "Medical Press," it appears that the average proportions of organic and mineral matters per gallon of London sewage, taken from ten different parts of the city, were as follows :—

NUMBER OF GRAINS OF SOLID MATTER IN 70,000 GRAINS (BEING 1 GALLON) OF SEWAGE.

	Organic.	Mineral.	Total.
In solution	15·08	40·66	55·74
In suspension	17·06	21·09	38·15
Total . .	32·14	61·75	93·89

LEICESTER SEWAGE.

In solution	13·49	56·51	70·00
In suspension	5·50	13·65	19·15
Total . .	18·99	70·16	89·15

TOTTENHAM SEWAGE.

In solution	9·49	45·01	54·50
In suspension	14·53	25·46	39·99
Total . .	24·02	70·47	94·49

In the Report of the Royal Commission on the pollution of rivers, issued in February, 1870, 21 analyses of London sewage are given, the averages of which are as follow :—

Total solid matters in solution, 64·54 in 100,000

parts by weight, which would be 45·18 in 70,000= 45·18 grains in a gallon.

In suspension	27·04	organic matter.
	42·46	mineral ,,
Total	69·50	in 100,000 parts by weight, which would be, per gallon
	18·93	organic.
	29·72	mineral.
Total	48·65	

In the same table of the Report are 29 analyses of the sewage of 16 other places—large and small towns—the averages of which are as follow:—

Total solid matters in solution, 77·74 in 100,000 parts by weight, which would be 54·42 in 70,000= 54·42 grains in a gallon.

In suspension	15·97	organic matter.
	14·05	mineral ,,
Total	30·02	in 100,000 parts by weight, which would be, per gallon
	11·18	organic.
	9·83	mineral.
Total	21·01	

In the foregoing 16 towns water-closets are in use, but by another table of analyses of the sewage of other places where water-closets are not in general use—called "midden towns"—it appears, from the same Report, that the proportion of solid matter in the sewage is quite as great; *e.g.*, 37 samples showed an average quantity of solid matters in solution equal to 82·4 parts in 100,000 parts by weight, or 57·68 in 70,000=57·68 grains in a gallon.

In suspension	21·30	organic matter.
	17·81	mineral ,,
Total	39·11	in 100,000 parts by weight, which would be, per

gallon	14·91	organic.
	12·47	mineral.
Total	27·38	

This is contrary to what one would suppose, but in these "midden towns" we know that a drain is or was commonly laid between the bottom of the midden and the sewer, by which means the fæcal and other matter was washed away in wet weather into the sewers, and this may account for there being even more solid matter in the sewage of these towns than in that of those where middens so drained do not exist.

§ XIII.—DISPOSAL OF SEWAGE.

In animal and vegetable life a constant round of changes is going on. Vegetation feeds upon decomposed vegetable and animal matter, converting substances noxious to the life of animals into healthy vegetation, when dissolved by water and taken up by the rootlets of the plants and converted into sap. The same vegetation, after a sufficient growth, is in its turn the food of animal life, which, in the process of its growth, throws off the refuse to feed vegetation again. Of the effete organic matter to be removed from the premises of houses, that which is of animal origin is destructive to the healthy life of animals, but it is the sustenance of the life of plants, and, through them, of the animals which feed upon them. To bring back the same elements which were poisonous to animal life in the form in which they were thrown off from it, they must undergo the complete transformation which passing into vegetable life involves, before they are rendered again fit and proper food for animals,—the elements, that is to say, not their husks or embodiment.

The process of cleansing sewage is essentially a chemical one, either natural-chemical or artificial-chemical. The sewage may be so exposed to the action of atmospheric air that the organic matter becomes oxidised and changed into harmless substances, which is a natural-chemical process.

Sewage should be conveyed to the earth as quickly as possible after its delivery at the end of a drain or sewer, and should be kept moving, for it is stagnation of the sewage which causes a nuisance, and it is precisely stagnation which prevents the sewage being used profitably. A water-logged soil will grow nothing of any value. There must be motion in the sewage,—slow, of course, but still, movement.

The pores of the earth are at all times filled with either air or water. When the one is expelled the other takes its place. Some part of the organic matter of the sewage—that which is already in the proper stage of decay to be assimilated by vegetation—is at once removed in that way; another part is stored in the earth, awaiting its further stages of decay, while, if the quantity be large, and more than these two processes can deal with, the surplus is carried down below the top soil, and would run off unpurified, but that, by laying drains at a sufficient depth, air is allowed to penetrate the pores of the earth, which changes the decaying organic matter into harmless substances, by a process of oxidation. If sewage be allowed to flow over a piece of land for a time, and then be shut off from that particular piece, it passes down into the drains, being followed in its progress through the pores by atmospheric air, which become filled therewith as they were before the air was expelled by the incoming sewage water. It requires a considerable time for the exhaustion of the sewage from the pores down to the level of the drains, for the exhaustion proceeds at a rate less and less every hour after the stoppage of the flow. If the sewage run on to a piece

of land for 6 or 8 hours, it may require the next 18 or 16 hours for the ground to be renewed with fresh air; so that the whole area should be divided into 3 or 4 areas, on to which the sewage should be made to flow in turns. This is the method of intermittent filtration, and by it a much smaller area of land is required to purify a given quantity of sewage than is required in the ordinary method of irrigation—not more than one-tenth as much; but there is less profit in its use. In order to apply sewage to land with profit, there should be an acre to from 50 to 100 of the contributing population—more or less according to the nature of the land and the crops grown.

Mr. W. Hope, V.C., who is an authority on the utilisation of sewage by way of irrigation, says that 50 persons to an acre are too many, and that a given quantity of sewage may be more profitably utilised by apportioning an acre to every 20 or 30 persons. Nevertheless it would seem that in situations where so much land as that would require cannot be had, an acre to from 50 to 100 persons suffices to cleanse the sewage.

Sewage irrigation, as ordinarily practised, is a kind of intermittent filtration, but instead of the pores of the ground lying exposed to air, as in intermittent filtration, for 16 or 18 hours, the sewage continues to flow over the same area for days together. The purifying effect of the porous ground over which sewage is made to flow intermittently is proportionate to the extent of its pores, or to its cubic capacity, within moderate range, so that if the drains are laid at a depth of 6 feet below the surface the purifying effect

of an acre of ground is equal to that of two acres when the drains are only half that depth. Drains are equally necessary whether the sewage be used by way of irrigation or by way of intermittent filtration, but in the former case the effect is dependent rather upon the extent of surface than the depth of drained ground. Different kinds of soil affect the cleansing of sewage differently. A clayey soil seems to possess the requisite properties in a greater degree than others: but if the land be a stiff retentive clay it is so dense, of itself, that a larger area is required, while sand of itself has no purifying properties other than those which porosity gives it. A mixed soil, of clay, sand, and lime, would seem to be the best.

In country places, where houses are situated widely apart, the sewage may be taken separately from each house to the nearest available piece of land. Where houses are near together it is more advantageous to lay a common sewer into which the separate houses may be drained.

The "Automatic Sewage Regulator," recommended by Messrs. Bailey Denton and Rogers Field, is the means of applying small quantities of sewage to land beneficially. Unless sewage comes on to land in sufficient quantity to cause a smart flow it cannot be dealt with properly; it cannot be turned in the various directions required from time to time. The regulator stores up in a tank the dribble of sewage from a few houses, and when the tank is full it is emptied automatically through a syphon pipe, and flows on to the land in a proper stream while it does flow. Thus each tankful may be turned on to any

part of the land requiring it, which may afterwards be allowed to rest and become aerated before other sewage is turned on to it. Mr. Joseph Hutchinson, 22, Whitehall Place, London, supplies all particulars required.

In some situations it would be impossible to place the sewage on land for irrigation or intermittent filtration, unless at too great an expense of pumping or otherwise.

In these cases the old plan of precipitation of the suspended matter is adopted, and the clarified liquid —the water—is run off into the natural watercourses. It must be admitted that by this plan, although it is economical in the first outset, the greater part of the fertilising value of the sewage flows off with the water, and that what is left behind in a solid state is not of much value—not more than one-seventh of the whole value,—the fertilising elements in solution being of a value six times that which is held in suspension, and which can be precipitated. Nevertheless, when it is impossible to adopt a system which saves more of the fertilising ingredients, this plan is one to which attention is turned with the view to apply it in the most effective manner. The sewage is received into tanks, or into tank-sewers, or tunnel-sewers, so arranged that it is allowed to come to rest in one of them while another is being filled. The precipitation of the solid matter is hastened and made more perfect by the addition of some ingredient (as sulphate of alumina), which causes the solid matter of the sewage to flocculate and fall quickly to the bottom, and, in order to prevent any fermentative action, by which a scum would rise to

the surface, a small quantity of lime is added to the sewage before it arrives at the end of the sewer.

Mr. Hawksley, C.E., has recommended for Birmingham a cheap sulphate of alumina, and afterwards a small quantity of the milk of lime, to cause an alkaline reaction, by which the effluent water is rendered clear and inodorous.

The system of Mr. F. Hille is similar; but he uses, in addition to lime, tar and the salts of magnesium, and the products arising from the calcination of lime. By this process the effluent water is brought to a state of comparative purity, and is afterwards filtered intermittently either through artificial filters or through land.

By the tank system the supernatant water is run off in a clear state, and it is the better way to run it off from the top downwards. This is done either by a floating weir or by a vertical pipe, made in sections to stand one upon another, a section being raised from time to time as the water sinks by flowing off. This vertical pipe may also be used as the overflow outlet.

Legal and other processes.—It has sometimes occurred that the distinction between those works which the Sanitary Authority are to do, as the public body, and those which owners of private property are to do at their own expense, has not been at once perceived. We propose, therefore, to point out a few of the sanitary laws and customs. There are two main divisions of the subject; (1) that which embraces what the Sanitary Authority are to do, and (2) that which private persons are to do. This latter, again, is subdivided into that which the owner

is to do, and that which is to be done by the occupier. The occupier, as a rule, is to remove all nuisances which are not caused by the want of structural conveniences on the premises; the owner is to do all structural work necessary to enable the occupier to keep the premises in proper sanitary condition; and the Sanitary Authority are to do the rest. But, in general, it is necessary that the Sanitary Authority should do their part of the work first, in order that the owners of property may be enabled to do their part, even as it is in many cases necessary that owners should do their part before the occupiers can do theirs; as, for instance, when the nuisance arises from the want of a house-drain, a sewer is first required with which it may be connected. It is stated in section 15 of the Act that "Every local authority shall keep in repair all sewers belonging to them, and shall cause to be made such sewers as may be necessary for effectually draining their district for the purposes of this Act." And in order to do this they may lay any sewer in any public road or street or other ground now occupied as a road or street, or which is intended to be given up for that purpose; and if it is necessary to lay a sewer through private land within the district in order the better to complete the system of sewerage, it may be so laid after giving reasonable notice in writing to the owner or occupier of the intention to do so (the land and all damages being, of course, paid for). And, further, if it is necessary in order to procure a proper outfall for the sewage, or for its distribution, that a sewer be laid beyond the district boundary, it may be so laid by giving three months' notice of the intention,

by advertisement in one at least of the local newspapers. The notice is to contain all such particulars of the intended work as may be sufficient for the understanding of the intention by every person interested, and it is to state where a plan of the intended work may be seen.

When land is required for the purposes of the Act it is taken either by agreement or under the powers of the Lands Clauses Consolidation Acts; but before putting in force any of the powers of these Acts the local authority are to publish in a local newspaper once at least in each of three consecutive weeks in November an advertisement describing the nature of the works for which the land is required, and stating how much is required, and where a plan may be seen; and are further to serve a notice in the month of December on the owner and lessee and occupier of the land, and requiring an answer whether the person assents, dissents, or is neuter in respect of taking the land required. The local authority then furnishes the information to the Local Government Board, and asks that they be allowed to put in force the Lands Clauses Consolidation Acts, whereupon the Local Government Board will direct a local inquiry to be made as to the propriety of making a provisional order in the matter, and if the government engineer who holds the inquiry approve of the plan the provisional order may be made, and the local authority are to serve a copy of it on the owner, lessee, and occupier of the land proposed to be taken.

As to serving the notices in the months of November and December as above-mentioned, they may be served

in September and October, or in October and November, provided that in either of these cases an inquiry preliminary to the provisional order shall not be held until the expiration of one month from the last day of the second of the two months in which the notices are given.

When it is desired to borrow the money for permanent works from the Public Works Loan Commissioners and to spread the repayment over a term of years, an engineering inspector of the Local Government Board usually holds a local inquiry into the merits of the proposed works, at which inquiry all parties interested may be heard, either for or against the proposal, and he reports for or against the request to the Local Government Board. Certain forms are furnished by the Board to be filled up by the engineer acting for the local authority, describing the nature and extent of the works and the estimate in detail, together with other particulars. At such an inquiry it is very desirable to have at hand every detail, both of the intended construction of the works and the estimated cost, the nature of the ground, and so on. The estimate is the chief thing to be inquired into, no doubt, and of course this cannot be accurately made out until both plans and sections are made, as well as detailed drawings, even though they be made out only in the rough; but it is certainly better on all hands (if time will allow of it, which it sometimes will not) that the plans should be wholly completed before the inquiry takes place, and not only so, but that duplicate plans and sections should be furnished. A civil engineer of much experience is apt to think

little of these formalities, and to rely upon the merits of his plan even though they may be unseen, but it is better not to trust to this.

By the 23rd section of the Act, "Where any house within the district of a local authority is without a drain sufficient for effectual drainage, the local authority shall by written notice require the owner or occupier of such house, within a reasonable time therein specified, to make a covered drain or drains emptying into any sewer which the local authority are entitled to use, and which is not more than 100 feet from the site of such house;" and goes on to say that if there is no sewer within 100 feet, then that the drain is to empty into a covered cesspool or other place.

Here, it may be observed, there seems to be some contradiction between this and the 94th clause, which has a provision that where the nuisance arises from the want or defective construction of any structural convenience, notice is to be served on the owner; and, in general, the owner is to lay the drain and do all other constructive work within the curtilage of his own premises.

If the notice is not complied with the local authority may, after the expiration of the time specified in the notice, do the work and recover the expenses from the owner.

The execution of the sewers is usually let by contract, as a whole, and the private drainage work is sometimes done by each owner of property employing whom he likes to do the work, and sometimes it is done by the same contractor who does the sewerage work, at a schedule of prices agreed upon previously. By the

latter method the owners of property have a guarantee that the prices are fair and equitable, without being, on the one hand, so small that the work cannot be properly done for them, or, on the other, exorbitant. By the former method the persons employed do not always know what the work is worth, beforehand, not being much accustomed to the kind of work, and if they are asked to say beforehand what they will do the work for they are more likely to over-estimate than to under-estimate the cost of it, and in that case the owner of the property suffers a loss, but it sometimes happens that he who is to do the work under-estimates its worth, and when that is so he either loses money or his efforts to recoup himself lead to bad work being done. Nevertheless there are advantages in employing local men to do the private drainage work, for they thus become, under proper supervision, educated to the kind of work required.

SANITARY WORK

IN

THE SMALLER TOWNS AND IN VILLAGES.

PART III.

WATER-SUPPLY.

SANITARY WORK

IN

THE SMALLER TOWNS AND IN VILLAGES.

PART III.

WATER-SUPPLY.

§ XIV.—QUANTITY.

A WATER supply is usually reckoned in point of quantity on the number of gallons per head of the population per day. At this rate the quantity actually supplied to towns varies from twenty in some to forty in others, in the majority of cases, and of these most incline towards the smaller number. There are exceptional cases where the supply is greater than the higher number, and others where it is smaller than the lesser number, but in most cases the quantity is between twenty and forty, and the average of all is probably not far from twenty-five. These differences in the requirements of different places seem to be attributable for the most part to the condition of the distributing pipes and the house-fittings. Where these are of bad construction the quantity of water unavoidably wasted is very great, and as the quantity

is reckoned upon that supplied rather than upon that used, the waste is included, and swells the amount to something beyond all reasonable limits when the quantities actually used for the separate purposes of a household are reckoned up.

But besides this cause of difference, resulting from the condition of the distributing pipes and house-fittings, there is a difference in the requirements between a purely agricultural district and a mining and manufacturing district. In the former a smaller quantity of water is required for personal washing, and especially for clothes-washing, and less also is required for the general cleanliness of houses in an atmosphere free from smoke and dust, than when the air is loaded with both; and according to the present constitution of rural sanitary districts many places are included in them in which a large quantity of water is required for these purposes.

It is not so much the question how little can people do with, or what quantity they use when they have to fetch it from long distances, but—what quantity they legitimately use when the houses and premises, and the clothes and persons of households, enjoy a condition of cleanliness.

The actual quantity used varies in an inverse ratio with the quantity of dirt about a household.

Where the water-supply is deficient, experience proves that neither persons, clothes, nor houses are kept in a state of cleanliness, and where circumstances make personal cleanliness impossible there must surely be misery. When a workman, whose occupation is a dirty one, comes home, if he could plunge into water

and get the dirt off him he would be set up for the evening, and be more inclined to stay at home than he is where all is dirt around him.

One must consider that there are two kinds of dirt: the one mineral, and inoffensive; the other is refuse organic matter. We do not feel defiled by contact with the one, but contact with the other is abhorrent, and there ought to be in every household a sufficient quantity of water to wash it off frequently. Those who suffer the dirt which is caused by the perspiration of the body to linger underneath the clothes, out of sight, are essentially dirty. We cannot all be rich, but we can all be clean.

The whole daily quantity of a water-supply is divided into three portions, viz., (1) for domestic use, (2) for public sanitary purposes, (3) for trades' purposes. The first two are everywhere required, and may be taken together as follows, where the distributing pipes and house-fittings are of good construction and their condition properly attended to. Where the occupation of the bulk of the people is not a dirty one, fifteen gallons per head of the population per day. Where the occupation of the bulk of the people is a dirty one, as in a mining and manufacturing district, twenty gallons per head per day. For trades' purposes the quantity varies greatly in different places. In some it is half as much as the quantity used for domestic and public sanitary purposes together, but it so completely depends upon the necessities of the locality that nothing definite can be stated for it. Whatever it may be in any locality it is to be added to the quantities given above. For

trades' purposes, water is mostly supplied by meter and charged at a price per thousand gallons. Supposing the quantity required for trades' purposes to be one-third of the quantity required for domestic and public sanitary purposes together, the total quantity would be from twenty gallons to twenty-seven gallons per head of the population per day, accordingly as the occupation of the bulk of the people is not, or is, a dirty one. And these would be the quantities where the house-fittings are of good construction and where proper precautions are taken to prevent waste. They are far less than the actual quantities supplied in many towns, but the surplus is wasted. The late Mr. James Simpson supplied to the Royal Commission on Water Supply a list of fifteen towns in which the average quantity is 21 gallons for domestic purposes, and 22⅓ gallons for all purposes; and Mr. Bateman supplied a list of eight or ten towns in which the average domestic supply is 25½ gallons, and the total supply 30½ gallons per head per day. In these averages the quantity taken for other than domestic purposes is about one-fifth of the domestic supply; but it is to be remembered that the quantity set down as for domestic purposes is not a measured quantity, but is the result of deducting the trade supplies from the total known supply, and therefore includes the waste, which, in some towns where the house fittings are of old construction, is very great; and when waste is prevented the fixed quantity required for trades' purposes bears a greater ratio to the domestic supply.

Examples of Charges.—The charge for the domestic supply is about, on an average, five per

cent. on the rateable value of the house, or one shilling in the pound; but it varies, both in different places and with the rental. The scale generally begins with houses not exceeding £4 a year, which are charged at the rate of 1*d.* a week, or 4*s.* 4*d.* per annum, and follows on nearly at the rate of one shilling in the pound, reducing, however, as the rent advances, so that a £50 house is perhaps charged at 47*s.*, a £75 house at 70*s.*, and a £100 house at 90*s.* Of course the original cost of the works influences the scale a little more or less, but the figures above are not unusual ones.

For trades' purposes water is supplied either by meter or by a scale of charges. There are some trades in which the quantity is not great enough to be metered. The price per 1,000 gallons is reduced with the increase in the quantity taken, and rapidly so where the water is supplied by gravitation.

For instance, the Manchester scale is, for a quarterly consumption not exceeding 6,000 gallons, 2*s.* per 1000. If the quantity be 10,000, it is 1*s.* 10½*d.*; if 20,000, 1*s.* 9*d.*; 50,000, 1*s.* 7½*d.*; 100,000, 1*s.* 3½*d.*; 150,000, 1*s.* 2*d.*; and so on until when the large quantity of 500,000 gallons per quarter is taken the charge is 10*d.*; for a million gallons, 7½*d.*, and 3 millions less than 5*d.* per 1000 gallons.

Then there are annual charges by scale, such as

£5	per annum	for a brickmaker's stool.
10*s.*	,,	for a smithy fire.
21*s.*	,,	for a slaughter-house.
21*s.*	,,	for a warehouse.
4*s.*	,,	for each cow.

4*s*.	,,	for each horse (private).	
7*s*.	,,	,,	at livery stables.
3*s*.	,,	for a 2-wheel carriage.	
5*s*.	,,	for a 4-wheel carriage.	
6*d*.	,,	per head in manufactories.	

Private baths are included in the charges for domestic purposes—as, indeed, would seem to be reasonable in all cases.

The domestic and public sanitary rate in Manchester is arranged in a way which has been since followed elsewhere. Instead of levying the whole amount required (1*s*. in the £) on house property, the rate is divided thus: 9*d*. in the £ on houses, which is called the domestic rate, and 3*d*. in the £ on all rateable property alike, including mills, manufactories, &c. It is evident that a supply of water, always under pressure in the street mains, day and night, is of value to property in general, as well as to dwelling-houses, and the proportion fixed upon at Manchester was 3*d*. for public and 9*d*. for domestic purposes; but the proportion is subject to variation; in Liverpool the public rate is 6*d*. and the domestic rate only 4½*d*.

The Leek scale for trades' purposes, other than those charged by meter, is as follows, *per annum*.

Barber's shop, using wash-hand basin .	5	0
Building brick walls (per cubic yard, 1*d*.)		
Building a house, one year's water-rate		
Builders' and wheelwrights' shops, per bench	0	4
Coopers and wood-turners, per person employed	0	4
Curriers, per person employed . . .	1	6
Cows, each	3	0

Horses, each	3	0
Carriages used for hire, each . . .	4	0
Ditto not used for hire	2	0
Drug shops, per person employed . .	2	0
Blacksmith's shops, per hearth . . .	2	0
Printing offices, per person employed .	1	6
Plumbers, painters, and paper-hangers, per person employed	0	4
Silk twisters, per gate	2	0
Slacking lime, per cwt.	0	1
Surgeries, per person practising . .	2	0
Water-closets in mills, workshops, and public buildings, each . .	10	0

Hotels, inns, and public-houses (having stables), 30 per cent on the domestic rate.

Eating-houses, 20 per cent. ditto.

Warehouses, lock-up shops, and offices, from 15 to 30 per cent. of the rate charged on dwelling-houses of equal value.

By meter the charge varies from 1*s.* 4*d.* per 1000 gallons for a consumption of 5000 gallons per quarter, to 1*s.* per 1000 for 10,000, 9*d.* per 1000 for 20,000, 7½*d.* for 40,000, 6*d.* for 100,000, down to 5¼*d.* for 200,000 gallons per quarter.

In the Stockport scale brewers are charged as follows, on the quantity of malt brewed per annum,

For any quantity not exceeding 50 loads .	£1	10	0
Above 50 loads, and not exceeding 100 loads	2	10	0
,, 100 ,, ,, 150 ,,	3	5	0

Above	150	loads and not exceeding	200	loads	3	17	6
,,	...	,,	,,	...	,,	.	.	.
,,	400	,,	,,	500	,,	5	19	9
,,	...	,,	,,	...	,,	.	.	.
,,	900	,,	,,	1000	,,	8	4	9
				....	,,	.	.	.
..	1400	..	,,	1500	..	10	3	6

Note, a load = 6 bushels.

At Norwich the charge for "domestic" purposes, which does not, however, include a bath in a house, which one would suppose to be one of the most necessary of domestic purposes, is 4*s*. 4*d*. a year when the rent (not the rateable value) is less than £5 a year. When that is as much as £5 and is less than £100, the charge is 5 per cent. on the rental, or 1*s*. in the £. When the rent (*i.e.*, the net rent at which the house would let to a tenant from year to year) is £100 or upwards, the charge is 4½ per cent. on the rental. The charges for other uses than those charged by meter are as follow, per annum:—

Greenhouses, 4*d*. per square yard of site.

Gardens attached to houses, and included in the rent, 2*s*. for every 10 rods.

Gardens not attached to houses, 2*s*. 8*d*. for every 10 rods.

One horse, 6*s*., and each additional one, 4*s*.

Each 4-wheel carriage, 6*s*.

Each 2-wheel carriage, 4*s*.

Street watering, 1*d*. per square yard watered once a day, or 2*d*. when watered twice a day.

For special protection against fire, and not to be used for any other purpose, 8*s*. for one opening, and 2*s*. for each additional one.

The house-service pipes are to be of lead, unless otherwise agreed upon, and are not to be of less than the following weights, namely,

⅜-inch pipe	5 lbs. per yard.	
½ ,,	7 lbs.	,,
⅝ ,,	9 lbs.	,,
¾ ,,	11 lbs.	,,
1 ,,	16 lbs.	,,
1¼ ,,	22½ lbs.	,,

These pipes are heavier than those in some other places, as, *e.g.*, at Yarmouth.

YARMOUTH.

½-in. pipe,	5 lbs. per yd.	
⅝ ,,	6½ lbs.	,,
¾	8 lbs.	,,
1	11 lbs.	,,
1¼ ,,	14 lbs.	,,

DURHAM.

⅜-in. pipe,	4½ lbs. per yd.	
½ ,,	6½	,,
¾ ,,	12	,,
1 ,,	19½	,,

COVENTRY.

-in. pipe,	7 lbs. per yd.	
	11 lbs.	,,
,,	16 lbs.	,,
	22 lbs.	,,

LEEK.

⅜-in. pipe,	4 lbs. per yd.
	5 lbs.
	7 lbs.
	11 lbs.

ALDERSHOT.

-in. pipe,	5 lbs. per lb.	
,,	7 lbs.	,,
,,	9 lbs.	,,
,,	11 lbs.	,,
,,	16 lbs.	,,
,,	22½ lbs.	,,

LAMBETH.

¾-in. pipe,	6¾ lbs. per yd.	
1 ,,	9¾ lbs.	,,
1¼ ,,	12¾ lbs.	,,
1½ ,,	15¾ lbs.	,,

§ XV.—QUALITY.

But it is necessary to consider the quality equally with the quantity of a Water-supply for general use, in respect of its hardness; and without going into any medical question of whether hard water is injurious for dietetic purposes, I think it will be found upon inquiry into the best testimony on this subject that, for general use, a Water-supply should not be of a hard character.

I separate the characters of water in this respect by saying that water of not more than 5 degrees of hardness, by Dr. Thomas Clark's scale, is soft water, and that 15 degrees of the same scale indicates hard water.

The Chemical Commission, appointed by Government to investigate the qualities of various waters, reported that "it may be useful to distinguish the quality known as the 'hardness' of water according as it is of a temporary or permanent character. Perfectly pure or soft water, when exposed to contact with chalk (carbonate of lime) is capable of dissolving only a very minute quantity of that substance; one gallon of water, in weight equal to 70,000 grains, taking up no more than 2 grains of carbonate of lime. This earthy impregnation is said to give the water two degrees of hardness. But waters are often found containing a much larger quantity of carbonate of lime, such as 12, 16, or even 20 grains and upwards in the gallon. In such

cases the true solvent of the carbonate of lime, or at least of the excess above two grains, is carbonic acid gas, which is found to some extent in all natural waters. But this gas may be driven off by boiling the water, and the whole carbonate of lime then precipitates in consequence, or falls out of the water, with the exception of the two grains which are held in solution by the water itself. The gas-dissolved carbonate of lime gives therefore temporary hardness, curable by boiling the water."

"Other salts of lime, such as sulphate of lime, are generally dissolved in water without the intervention of carbonic acid gas, and therefore remain in solution, although the water is boiled, imparting hardness."

The Commissioners also say, "In the washing of the person the saving of soap by the use of soft water is most obvious. For baths, soft water is most agreeable and beneficial, and might contribute greatly to their more general use. Its superior efficiency to hard water in washing floors and walls is calculated also to promote a greater cleanliness in the dwellings of all classes, both within doors and externally; while in the occasional domestic washing of linen the smaller preparation necessary for washing in soft, as compared with hard water, the saving of soap which would then be sensible to its full extent, and the more easy and agreeable nature of the operation, would make a supply of soft water in a high degree desirable."

The Royal Commission on Water-Supply, who reported in 1869, took evidence on the question whether hard or soft water is to be preferred for a general supply.

Dr. Edmund A. Parkes, in answer to the question (No. 3126), "Would 16 or 20 degrees of hardness be prejudicial?" says "I think that that degree of hardness would be certainly prejudicial. I think that very probably it might disagree with a great many people; but supposing it reached to 8 or 10, or 12 degrees of hardness from carbonate of lime, it might be considered probably good water as far as that was concerned, but I should draw a marked distinction between that and the hardness arising from sulphate of lime, or sulphate of magnesia, or chloride of calcium, which would certainly disagree in much smaller quantities, so that the goodness of water for drinking purposes I would estimate according to its permanent hardness rather than according to its temporary hardness."

Dr. Lyon Playfair says, in answer to question No. 2646, *et seq.*, that, as a sanitary question, if the water is otherwise pure he does not think that mere hardness is of much importance as to health, but that it is of the greatest importance as regards the economical use of the water; that less soap would be required; that cleanliness is promoted by the use of soft water, both with regard to personal cleanliness and washing, and that there is considerable economy in the use of soft water, compared with hard water, in respect of wear and tear of clothes in washing. Evidence of similar import was given by Mr. John Simon, Dr. J. A. Wanklyn, Professor Odling, Dr. W. A. Miller, and Dr. Angus Smith.

§ XVI.—SOURCES OF SUPPLY.

Brooks and small streams in valleys are not desirable sources of water supply; the quantity of organic matter they contain, in comparison with the quantity of water flowing in them, is greater than that contained in the water of other sources.

Other sources are, (1) Rivers, (2) Springs, (3) Moorland tracts of ground, where the rain-water, falling upon them, and running off in small and rapid streams, is caught in reservoirs at a high elevation; and (4) Deep wells.

As to rivers, running water contains free oxygen, absorbed from the atmosphere, and the more so where it has a quick motion over a rough bed, which causes its surface to be broken up, and exposes a greater number of particles of water to the atmosphere than where the motion is slower, over a smoother bed. Organic matter in a state of decay, which I have elsewhere called "effete organic matter," is, as it were, seized upon by the oxygen in the water and chemically changed into harmless substances, after the action has continued for a sufficient length of time.

It is a matter of common observation that the discoloration of rivers by the polluting matters poured into them from populous places gradually fades away, and that at some considerable number of miles below, if no other pollution takes place on the way, the water is clear, and in some cases quite fit to drink; and if

the water of rivers could flow far enough away from one town before it were taken for the supply of the next one, the organic impurities would probably become wholly changed into harmless substances; the difficulty is to ascertain in what distance or in what time this effect takes place; either distance or time will vary with the relative quantities of polluting matter and of water, and there is nothing but supposition to go by in estimating at what distance from the polluting source water may safely be taken for domestic use lower down the river. It cannot very well be proved that they are wrong who advocate a river source for a supply of water, even when it is well known that the water is daily contaminated higher up the stream. The strongest argument in support of such a source is found in the want of proof that the water is injurious to the health of those who constantly drink it. This is but negative evidence in its favour, and even this is only true in some cases, as, for instance, in the Thames at Hampton, from which source a great part of London is supplied, although it is well known that the sewage of some considerable towns is poured into the river above that point.

On the other hand, as to the disappearance of colour by long-continued flow, it is proved positively that water may be quite bright and yet contain matter in solution which disqualifies it for domestic use.

Springs are more copious, and constant in their flow, from some of the geological formations than from others. From the chalk, the oolite, the new red sandstone (Bunter division), and the millstone grit, springs are more copious and constant than from other

formations, except the mountain limestone, which has many fissures and caverns; and some of the springs from this formation yield large quantities of water perennially, varying but little throughout the year, while others, though tolerably constant during years of average rainfall, almost cease to flow after a long drought. This seems to be owing to the comparatively small extent of ground upon which the rain falls, combined with its great porosity; while the ground from which the more perennial springs issue is of greater extent and comparatively of more general compactness.

The late Mr. Beardmore estimated that the water which falls upon the chalk district of the river Lea holds out for at least sixteen months.

Some springs from the oolite are reported to be nearly constant the year round, others varying about 30 per cent. as between the average and the minimum flow. I gauged daily during the years 1860 and 1861 several springs which issue from the millstone grit at Upperhulme, near Leek, with the following results:—During the year 1860 the average daily quantity was 355,266 gallons, and the least quantity on any day was 305,453 gallons. During the year 1861 the average daily quantity was 333,716 gallons, and the least quantity on any day was 258,600 gallons. Other springs have been proved to be equally or more constant in the new red sandstone, but in the mountain limestone they are more variable—perhaps because of the fissures being more open. The original chief source of the Bristol water supply was some copious springs issuing from this formation at Chewton Men-

dip, which ran for a long time at the rate of two million gallons a day, but about ten years afterwards these and other springs from which the supply was derived fell off considerably; resuming their full flow again, however, afterwards.

Below any level at which the water could issue in springs the absorbent rocks hold water as in a basin, and it may be procured by sinking a well. When the ground through which a well is sunk is porous from the top downwards, the quantity of water met with increases with the depth of the well, but in some situations the water-bearing stratum is overlaid with strata of an impervious nature, which keep down the water, under pressure. In sinking a well in such a situation but little water is met with after the surface or top water has been passed through, and this, when of bad quality, is usually stopped out by a water-tight lining. But when the depth to the water is great it is not necessary to sink a well all the way to it; after sinking to a sufficient depth to form a lodge for the water, and afford room to fix the pumps, the remainder may be bored. When the water is reached it bursts up suddenly and fills the well. The first great undertaking of this kind was at Grenelle, in the province of Artois, in France, where a bore hole was made down to the lower greensand, under the chalk, to a depth of about 1,800 feet, when the water suddenly rose through the bore hole, and was forced up many feet above the surface. Since this successful attempt to procure water in this way the name Artesian has been given to such a well, from Artesium, the ancient name of Artois. The blow-wells, in the low-lying pa

of Lincolnshire act in the same way, although on a smaller scale; the overlying clay being bored through to the chalk beneath. In all such cases the water which is thus procured must first have fallen upon ground much higher than the site of the well, and upon the outcrop of the absorbent stratum pierced by the boring, through the fissures of which it descends and accumulates under the clay or other retentive strata of which the low-lying ground consists. A well sunk through the clay into the chalk at Kingston, in Surrey, threw water up to the surface, being a true Artesian well. Its temperature was, however, too high for the purpose for which the well was sunk. The strata passed through were as follow :—

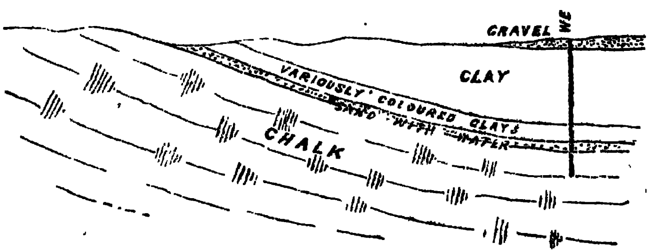
11	ft.	clay and gravel.
2	,,	gravel.
245	,,	blue clay.
57	,,	clay of various colours
4	,,	marl.
½	,,	vein of sand.
9	,,	marl.
½	,,	vein of sand.
5	,,	marl.
12	,,	dark sand.
25	,,	light coloured sand.
99	,,	chalk, with flints.
470	ft.	

The following is a short description of an Artesian well to be sunk in the same locality :—Well and bore

hole to be sunk to an estimated depth of 500 ft. Two 6-ft. lengths of cast-iron cylinders, 7 ft. diameter, to stop back the top water. Shaft lined with 9-in. brickwork, 6 ft. clear diameter, to be continued to a depth of 200 ft. Cast-iron bore-pipe, 12 in. diameter, with turned joints, to commence here and go down to the chalk, reducing the size only when necessary. The pumps to be at a depth of 80 or 90 feet below the level to which the water may rise. Estimated cost, £1,350.

Figure 30 illustrates such a well.

Fig. 30.



The publishers have very kindly offered me the use of a wood-cut from Mr. Hughes's book on Water Works, which shows, better than anything I could give, how it is that, when an impervious stratum of clay is sunk or bored through, water is found, and rises towards the surface, having its origin, in this case, in the rain falling upon the high ground about Tring on the one side and Knockholt on the other. The following are Mr. Hughes's own words :—

"In this section A is the gault clay, an impervious

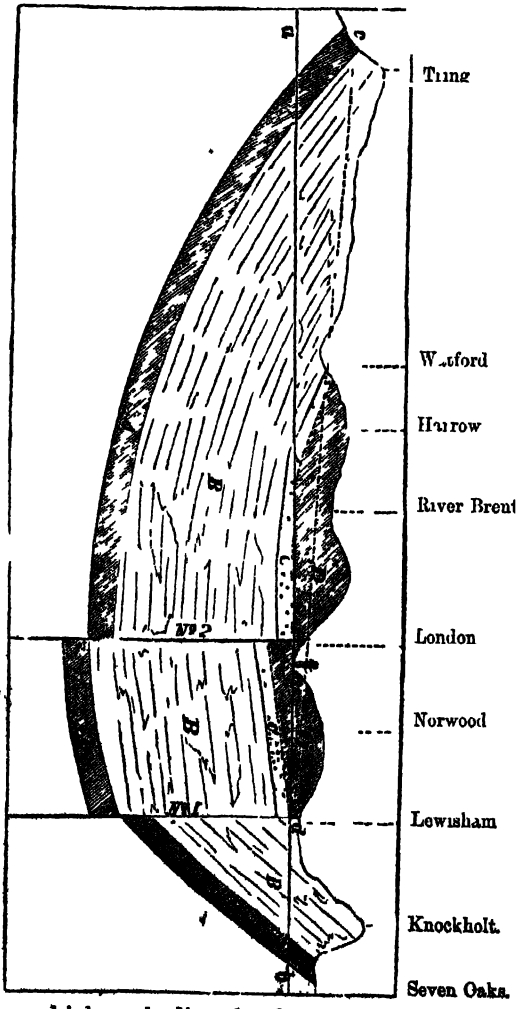


Fig 13

stratum, which underlies the firestone, chalk marl, and

chalk. The firestone and chalk marl are not shown in the section, because it is believed in this chalk basin the water penetrates through both of these, and is really not stopped till it reaches the gault. In the south downs, however, it is otherwise, for there Lydden Spout, and other copious springs are thrown out by the chalk marl. B is the great mass of chalk 800 or 1000 feet in thickness. The tertiary or Thanet sands, resting on the chalk, are marked C, and the impervious mass of London clay is marked D. The level of high water mark in the Thames is represented by the horizontal line *a b*, and the presumed line of saturation or height to which the water from the chalk will rise at any point between London and Tring, is represented by the inclined line *c d*, drawn from the top of the gault below Tring to tide level in the Thames at Lewisham, where the chalk is exposed in the basin of the Thames. It will be observed that in this section I have not shown the beds in one continuous uninterrupted basin-shaped arrangement, but intersected by two faults, marked No. 1 and No. 2. The fault No. 1, which brings down the London clay D to the level of, and in contact with the chalk, is clearly exhibited on the North Kent and London and Brighton Railways, both of which it intersects at New Cross, in a north-east and south-westerly direction. It has been well described by the late Mr. De la Condamine, in a paper read before the Geological Society of London, in June, 1850.* With respect to the fault No. 2, although not exposed at the surface, we have good evidence of its

* Published in Vol. vi. of the Quarterly Journal of the Geological Society, p. 440.

existence from well sections. Thus, the depth to the chalk below Trinity high water mark at Gray's Inn Lane, the Hampstead Road, Tottenham Court Road, and the Regent's Park, varies from 80 to 100 feet; while at Trafalgar Square, Wandsworth, and Chelsea, the depth varies from 250 to more than 300 feet, which shows either a fault or a very great curvature of the strata. Mr. Prestwich believes that this fault or axis of elevation, whichever it be, passes along the valley of the Thames, in an east and west direction. It is clear that this fault as well as the one at Lewisham, No. 2, would be intersected by th line of our section. The main drainage of the chalk formation is not so much interfered with by these faults as might be supposed at first sight. The line *c d* shows the height to which the chalk is probably saturated with water, according to the views first promulgated by Mr. Clutterbuck, and afterwards corroborated by the Dean of Westminster and other eminent geologists. The drainage of the chalk will still take place at *d*, notwithstanding the faults, because the communication between the separate masses of chalk is still uninterrupted, the fault being probably not filled up with impermeable clay and made into a puddle dyke, as happens in some districts. According to the views of Mr. Clutterbuck, the water will rise in wells between Tring and London, to the level of *c d*, and he has found by measurements of numerous wells intermediate between the two places, that the water stands at, or nearly at this height. It will be observed that the ground at Watford lies below the line of saturation *c d*, and this accounts for the numerous springs which

break out in the meadows there, and for the fact, that every excavation, made only a few feet in depth, is immediately filled with water. Again, it will be observed, that a part of the London clay district, close to the metropolis, lies below the line of saturation. This is precisely the condition under which artesian wells may be expected to yield a stream of water that will overflow the surface. On boring down through the London clay, D, to the chalk on either side of the fault No. 2, we come to water which is acted on by the pressure from Tring or Knockholt as the case may be, and which, as soon as the boring is effected, rushes up through it and rises above the surface, namely, to the the line *c d*. This is the explanation of many overflowing artesian wells in the neighbourhood of Fulham, Brentford, and other places in the valley of the Thames."

Common wells, though they may be deep, depend for their water upon the area immediately surrounding them, the rainwater falling upon which sinks downwards and laterally towards the bottom of the well, and the quantity procurable may be likened to the contents of a cone, the base of which is the area 'round the well, and its apex the bottom of the well, the contents being renewed from time to time as the rain falls. The extent of this area, or base of the inverted cone, is the greater the more porous the ground is, for any given depth of well, for there is in every kind of ground a minimum horizontality which the water can assume, under any given degree of exhaustion by pumping, its percolation to the well being hindered by the density of the ground through which

it passes, and the greater the density the steeper the incline assumed by the sides of the water cone. In practice these theoretical deductions are interfered with by the existence of faults, filled more or less with impermeable material. It is said that at one of the wells at Liverpool, 210 ft. deep, in the new red sandstone, the shallow wells around were affected by the pumping to a distance of $1\frac{3}{4}$ miles from the shaft.

A well sunk in the new red sandstone at Wolverhampton yielded but little water, being within a quarter of a mile of a great fault, limiting the extent of surface on that side to that distance.

Good water is obtained from uncultivated tracts of moorland. It is obtained by storing in reservoirs that which flows directly off the surface, and that which sinks into the ground and issues in springs within the watershed area. Knowing the quantity of water required, the area from which it is to be collected may be determined according to the amount of rainfall of the locality. It is necessary, in order to do this with something like precision, to obtain the register of the rainfall for a number of years. If the rainfall has not been gauged within the particular area, the water from which is to be appropriated, it is necessary that the position of the area on which the gauges may have been fixed, be one in which similar meteorological occurences take place habitually; as, for instance, at a similar height above the sea-level; exposed to similar currents of air; sheltered by hills in similar relative positions and of similar height, or that both situations should be equally unsheltered. The best position for a rain-gauge is in an open piece of ground, not near houses or

trees, and from 6 to 12 inches above the ground; the nearer the ground the better, so that it is sufficiently high to prevent the splashing of water that falls outside it leaping into the mouth of the gauge. Five inches diameter is reckoned to be as good a size as any for the mouth of the gauge. Rain-gauges are made in various forms, and that in which the depth registered is most easily ascertained, carries a graduated rod attached to a float, which, rising with the water in the gauge, shows the depth fallen; but this kind is open to the objection that the face of the rod catches rain, which runs down it into the gauge and causes a greater depth of water to be registered than actually falls. Another kind has a graduated glass tube attached to the body of the gauge, in which the water rises equally with that in the body of the gauge; another kind merely receives the water, which is measured by pouring it out into a separate glass tube to ascertain the depth fallen. There is also another kind which has a float unattached to any rod, a graduated rod being used only at the time of measurement.

The register of rainfall for a number of years having been obtained, an average is taken. If the yearly depths of rain be examined separately, it will probably appear that they vary much from each other, and that the greatest depth in any one year is about twice the least in any other. It will probably be observed also that for two or three years together preceding or succeeding the year of least rainfall, the amount is less than the average of all the years, and that the mean depth of three consecutive dry years is about one-sixth less than the average; also, that the

least depth in any year is one-sixth less than this mean of three dry years.

Experience has shown that the quantity of water which can be caught and stored in reservoirs and delivered out daily for use is not so much as that due to the average of a number of years, and is not more than that due to the mean of three consecutive dry years, which has proved to be, in numerous instances, very nearly one-sixth less than the average, all the rest going past the reservoir in excessive floods. Thus, if a table of rainfall be examined, extending over a sufficient number of years, it may show the average yearly depth to be 36 inches. In some one year the least depth will probably be found to be about 24 inches, and taking any three consecutive dry years, the mean of them will probably be about one-sixth less than the average, or 30 inches, and it is this depth and not the average, which is to be reckoned upon; and the daily quantity required being known, the necessary extent of watershed area is ascertained. But the actual quantity to be dealt with is always less than the rainfall registered by a gauge, for the gauge registers the depth that falls, and from that depth must be deducted the quantity evaporated and otherwise lost on its way to the reservoir.

In his evidence before the Water Supply Commission in 1867, Mr. Bateman said that "according to the declivity and the geological character of the country, and the cultivation and the amount of vegetation, the quantity which is taken up by vegetation, or is evaporated or lost to the rivers, varies from about 9 inches to 16 inches, the smaller quantity being of

course that where the rocks are the hardest, and the declivities are the greatest, so that the water comes down in floods. If we take 12 inches as the mean between those extremes, it will leave the net available produce of these districts" (speaking of the Welsh hills from which he proposed to take water). This loss is taken from returns of actual gaugings in various places. He says, "In Manchester we have actually collected and measured in reservoirs 33 in the average of two or three dry years. Out of a rainfall of 45¾ inches we have actually collected and discharged 33 inches." This would be a loss of 12¾ inches in the year.

The late Mr. Thomas Duncan gave evidence before this Commission. He was the acting engineer of the Liverpool Water Works for many years, and had very good means of ascertaining by gauges the actual quantity of water collected and used out of the total quantity that fell. Five-sixths of the ground from which the gravitation supply is derived, consists of moor and sheep pasture, covered with heather, and some portion of it is mossy, the geological formation being chiefly millstone grit. A very small portion of it was ploughed, not one-fiftieth part; the whole area of the gathering ground being about 10,000 acres. With reference to the loss by evaporation and otherwise, the question is put to the witness, and referring to some tables he had drawn out, "You do not appear to have had a loss in any one year of as much as 12 inches. That is to say, in 1861 the rainfall was 46·38 inches, and then, taking the quantity you realise, which is 35·77 inches, that is slightly under 11 inches.

If you take the next year as 48·51 against 40·08, that is a loss of 8 inches. In the next year it is 51·01 against 40·72, that is under 11 inches again. In the next year it is 39·035 against 27·85, and in the next year it is 34·80 against 23·35, making a loss of 11¼ inches. Therefore, whatever your rainfall be, whether it be large or small, the actual loss would seem to be very nearly the same?" A. "The amount of evaporation and absorption does not vary much."

Mr. Hawksley has stated (Minutes of Proceedings, Inst. C. E., vol. 31) that the loss varies in these islands "from 10 inches per annum as a minimum to 18 inches as a maximum. The minimum occurred very rarely—indeed, only in the case of bare precipitous mountains, consisting of non-absorbent rock, such as slate or granitic rock. From that surface all the rain that fell could be gathered, with the exception of about 10 inches. But the case was very different where the surface was covered with soil and peat, where it became flat moorland on the summit, and more so where the land was cultivated and thrown into the character of a sponge. In general, however, with mountain watersheds, where the intermediate condition existed, the actual ascertained loss amounted to from 13 inches to 15 inches per annum, according to the situation and some local circumstances, and might be taken at a mean of about 14 inches per annum."

Supposing the situation to be one where this average loss of 14 in. in depth would occur, it is to be deducted from the 30 in. representing the mean annual depth of three dry years, as above, leaving 16 in. in depth over the whole drainage area, which represents the actual

quantity of water to be dealt with, being 363,000 gallons in a year from every acre of drainage area, or very nearly 1,000 gallons per day per acre, and if 20 gallons per head of population per day be allowed there would be required an acre of collecting ground for every fifty people, or for every ten houses (there being, on an average, about five inhabitants to a house). Thus, if the population to be supplied be 10,000, the daily quantity of water required would be 200,000 gallons, and the area of collecting ground 200 acres, if the rain-fall be 36 inches.

Where, as above stated, the whole of the available quantity of water due to a given area may be taken for the supply of a population, it will in general be necessary to afford water-compensation to the streams and mills out of a separate reservoir; but in some cases water-compensation is given out of the same reservoir from which the supply to the population is derived, in which case the watershed area must be one-half greater than that above stated.

The next step would be to find a suitable site for the construction of a reservoir into which the water falling upon the drainage area would flow, and the next step would be to determine the size of the reservoir—the quantity of water it should hold. We know that many storage reservoirs have failed to contain a sufficient quantity of water to last through a long drought at the rate of delivery out of them which had been calculated upon as the daily supply.

In the first place, averages of many years' rainfall have been taken without deduction for the excessive floods which cannot be stored in reservoirs of any

practicable size, and a certain proportion of the average has been deducted for loss by evaporation and absorption, without regard to the absolute quantity of that average. Thus, when the average annual rainfall has been ascertained to be, say, 45 in. in one place and 30 in another, one-third, or some other proportionate part has been deducted for loss, and the remainder set down as the available quantity, giving in the first of these assumed cases 30 in. available and in the other 20; and it is quite possible that by accident both these might be the true quantities available in certain situations, if the precaution were taken to deduct excessive floods which swell the average beyond a point that can be dealt with in any reservoir that could be practicably constructed; but experience has shown that the loss by evaporation and absorption does not bear any fixed ratio to the rainfall, or to its average amount, and that it is almost a constant quantity in any year in the same place, whether it be a wet year or a dry one. These two sources of error are avoided by first deducting one-sixth, or thereabouts, from the yearly average, and then deducting an absolute depth, being that due to the loss by evaporation or absorption, the result being a quantity which may fairly be relied upon. The depth of rainfall to be deducted for loss cannot be directly ascertained; from a water surface the evaporation is about 30 in. in depth in a year, but from the surface of a collecting ground it cannot be directly measured. The way in which it is ascertained is by the indirect method of deducting the known quantity collected from the known quantity

resulting from a certain depth of rainfall on a known area of ground, the difference being the loss.

But another source of error has been to underestimate the length of time droughts may continue in certain situations, and not sufficiently taking into account the number of days on which rain falls in any given period (as a year), which varies very much in different places; for the fewer wet days there are in a given time the greater number of days' supply should the reservoir hold, whatever be the annual rainfall, and consequent daily regulated supply.

Large storage reservoirs, such as those now under consideration, are usually made by constructing an embankment across a valley, and making use of the hollow thus formed by nature to hold the quantity of water desired. The best site for a reservoir, therefore, is one where (1) a bank can be made under or by which water cannot pass, when dammed up to a considerable height; (2) where the ground has sufficient stability, not only in itself in its natural state, but afterwards when it may be more or less penetrated by the water penned up, so that no slip may occur; (3) where a wide and comparatively level expanse of ground exists below which the sides of the valley approach each other so that a short bank, and one not too high, may impound a large quantity of water; if the first requirement exists the fourth will be secured, viz., that there should be a sufficient quantity of retentive material to form a core, or trench and wall, of watertight material, such as clay.

§ XVII.—GAUGING WATER.

The quantity of water supplied by a pump may be measured by the capacity of the working barrel and the speed, deducting from the quantity so found about 10 per cent. for leakage of valves and other losses: and water is sometimes measured in a similarly mechanical manner by meters; but when the water flows, or can be made to flow, from a pond, over a weir, or through a notch in a plank or iron gauge, the quantity may be ascertained in the following manner, provided the thickness of the sill over which the water falls be properly regarded, and providing the weir or gauge be truly level, and that proper precautions be taken to prevent the water passing under it or past the ends.

The velocity with which water falls over such a barrier follows the same general law which affects other heavy bodies falling freely,—that is the force of gravity. A heavy body falls 16·08 ft. in the first second of time after its descent from a state of rest, and acquires at the end of that time a velocity of 32·16 ft. per second, which is called the force of gravity, and is represented by the letter g. The formula is $V = \sqrt{2\,g\,H}$, when $V =$ the velocity in feet per second; $g =$ the force of gravity, $= 32·16$; and $H =$ the height in feet. Therefore $V = \sqrt{64·32\,H} = 8·02\,\sqrt{H}$.

In the case of a weir or a notch-board the height H is synonymous with the depth of water. The depth

to be calculated upon is not that immediately over the sill of the weir, but is the whole height from the sill to the level of the water above the weir where it is out of the influence of the current. When water approaches a weir, or notch-board, the surface is drawn down for some feet up-stream, being influenced by the draught of water through the passage, and in measuring the depth it is necessary to take it at some point out of the influence of the current.

It has been stated above that the velocity with which water falls over a weir is as the square root of the depth, and when the whole depth is taken the velocity due to it is that of the lowermost filaments or threads (as it were) of the sheet of water flowing over. These are pressed outwards by a force which is that of the whole head of water, from the sill up to the level of still water, and did they issue from an orifice at that depth would spout out much farther than they can do with the superincumbent sheet of water upon them. The uppermost filaments have no velocity which is due to the pressure of a head of water, and the velocity which they do acquire is caused by those below slipping horizontally from under them and letting them down gradually from the bottom upwards, causing a depression over the sill, which gives an inclination to the surface of the water for some few feet above the weir or notch-board.

This inclination of the surface is differently produced from that of a river in train, and is due to the loose end of the stream, whereby the lowermost particles escape faster than those above them, the whole number becoming amalgamated into one stream, which

takes a direction due to that filament which is at the depth due to the mean velocity of the whole stream. The velocity of the fluid threads at every part of the depth being as the square roots of their depths below the surface, the mean velocity of them all is necessarily $\frac{2}{3}$ of that of the lowermost, and the whole sheet of water assumes the curve which that filament would do which is at the depth to which the mean velocity is due, if it could issue alone. The point in the depth at which the mean velocity of the whole takes place is at the depth of $\frac{4}{9}$ of the whole depth, and the mean velocity is that due to $\sqrt{\frac{4}{9} d} = \frac{2}{3} \sqrt{d}$, which is, when the constant multiplier is interposed, $\frac{2}{3}$ of 8·02 $\sqrt{d} =$ 5·35 $\sqrt{d}$, which is the true expression of the mean velocity of all the filaments of water passing through the notch, or over the weir; and were there no obstruction to the flow the quantity discharged would be found by multiplying this velocity into the depth and into the length of the weir; but by no form of construction can the actual discharge reach this theoretical discharge, because, first, the theory assumes the falling body to fall *in vacuo*, whereas in practice it falls through the air, and although atmospheric air at a barometric pressure of 30 inches of mercury is of a density only about the $\frac{1}{815}$ part of that of water, yet it offers some small resistance; and, moreover, while the theory takes no account of friction against the bottom or sides of the notch or weir, or of the divergence of the particles of the stream passing through the opening, the actual discharge is diminished by these influences also. The more abrupt the opening the greater are the disturbances of the flow. If we

were treating of hydraulics in general we should see how, by the appliance of wing-boards above the weir, or, in the case of orifices wholly below the surface, by adjutages below the opening, the discharge is increased to almost the whole quantity indicated by theory, but those are not the circumstances under which water is gauged in ordinary practice.

In calculating the quantity discharged the depth enters twice into consideration. In the first place it is an element of the sectional area of the stream, and in the second of the velocity. The sectional area is as the depth, and the velocity as the square root of the depth. The cubic quantity discharged is therefore as $d\sqrt{d}$ or as $\sqrt{d^3}$. If the quantity be taken in cubic feet per second per foot in length of the weir it is $5{\cdot}35\sqrt{d^3}$ by the theory of falling bodies, the depth being measured in feet; and if it be taken in cubic feet per minute it is $321\sqrt{d^3}$ per foot in length of the weir. But it is more convenient to measure the depth in inches, in which case the constant 321 must be divided by the square root of the cube of 12, or $\sqrt{1728} = 41{\cdot}57$, and $\frac{321}{41{\cdot}57} = 7{\cdot}72$, the constant of the theoretical quantity per foot in length of weir when the depth is measured in inches and the quantity in cubic feet per minute. If we put $l =$ the length of the weir in feet, this quantity would be $7{\cdot}72\, l\sqrt{d^3}$.

But practice has proved that not only is the actual discharge less than that of theory under every condition of a weir, but that the constant multiplier varies with both the length and the depth. By measuring in large tanks the actual quantities discharged under

various conditions of depth of water, length of weir, and thickness of lip, and dividing these quantities by the areas of the openings, certain coefficients have been found which bear the same relation to unity which the quantities discharged bear to the theoretical quantities, under the same conditions of length and depth.

Various observers have found the coefficient to be from about ·58 to about ·68, and if we take the mean of all to be ·623 the theoretical constant 7·72 would be reduced to 4·81, so that if we put Q = the quantity discharged in cubic feet per minute, d = the depth of water in inches, and l = the length of the weir in feet, $Q = 4{\cdot}81\, l \sqrt{d^3}$.

By this formula it is assumed that the quantity is proportionate to the length, but it is not exactly so, for the shorter the weir, compared with the width of the stream and with the depth of water flowing over it, the greater should be the proportionate diminution of discharge due to the contraction of the two ends of the weir; and Mr. Francis, in the formula resulting from his experiments at Lowell, U. S., makes a correction for this. His formula is $Q = 200\,(l - 0{\cdot}1\, n\, d) \sqrt{d^3}$, d being taken in feet, but if we take d in inches, and divide the constant 200 by the square root of the cube of 12, $Q = 4{\cdot}81\,(l - {\cdot}00833\, n\, d) \sqrt{d^3}$, n being the number of end contractions.

The effect of the end contractions in the case of a weir with one opening five feet long, and a depth of water of six inches, is to reduce the quantity discharged by about seven cubic feet per minute; thus, $4{\cdot}81\, l \sqrt{d^3} = 4{\cdot}81 \times 5 \times 14{\cdot}7 = 353$ cubic feet per

minute, and $4{\cdot}81\ (l - {\cdot}00833\ n\ d)\ \sqrt{d^3} = 4{\cdot}81\ (5 - {\cdot}00833 \times 2 \times 6) \times 14{\cdot}7 = 346$ cubic feet per minute, or by about 2 per cent. in this case.

Except those of Mr. Francis, the most important experiments on a large scale which have been made on the flow of water over weirs were made by Mr. Blackwell, on the Kennett and Avon canal, in 1850. These were made from a perfectly still head, the area of the pond from which the water flowed being upwards of two acres in extent.

These experiments were upwards of 200 in number, and were made with weirs of three feet, six feet, and ten feet in length; with thin iron plates; with planks two inches thick; and with broad-crested weirs, resembling ordinary weirs on rivers, the width of crest in the experiments being three feet. The coefficients were found to vary with the depth of water and also with the length of weir, and with the thickness of the lip.

The following is an analysis of those experiments of Mr. Blackwell which, in point of dimensions, come most under the conditions of ordinary practice;—I mean, of course, which, within the scope of the experiments, are most proportionate to the dimensions of ordinary stream gauges. The gaugings of exceptional depths with certain lengths are most valuable, as related in full by Mr. Blackwell in his paper contributed to the Institution of Civil Engineers, but I have been content to adduce the results within a depth of nine inches; also not to include the experiments on weirs with wing-walls, and those made with short wide-crested weirs.

The general formula is $Q = c\, l \sqrt{d^3}$, in which Q = the quantity of water discharged per minute; d = the depth in inches from the surface of still water to the lip of the weir; l = the length of the notch in feet, and c = a constant multiplier found by experiment to equilibrate the terms Q and $l \sqrt{d^3}$. This constant, c, is found by measuring in a tank the quantity of water which falls in a certain time from a notch of a certain length with a certain depth of water flowing over it; each one of these items being a subject of measurement. The constant, c, is therefore arrived at independently of the relation between the theoretical result and the practical result. But inasmuch as the conditions under which experiments are made must be limited, while those of practice are unlimited, it is very useful to compare the actual discharge under given conditions with that which is due to the theory under the same conditions, and this is best explained by dividing the constant multiplier, found by experiment to be necessary, in each of the given conditions, by the constant multiplier of the theory. The result is the *coefficient*, which bears the same relation to unity as the actual discharge bears to that of theory. In the following table it is the result of dividing the actual constant in each case by 7·72, the theoretical constant, when the quantity is taken in cubic feet per minute, the depth in inches, and the length in feet. Thus, $\frac{5·17}{7·72} = ·67$, the mean coefficient of all lengths and all depths over notches in thin plates. Averages are not always to be relied upon, but it may be observed that the combination of all lengths with all

depths, within the range of these experiments (which, indeed, were numerous), shows an average constant of 5·17 for thin plates, 4·35 for 2-in. planks, 3·93 for weirs with wide crests sloping 1 in 18 across, and 3·66 for similar weirs with level crests; the corresponding coefficients being ·670, ·563, ·508, and ·474.

Analysis of Mr. Blackwell's Experiments on the flow of water over Weirs, within the limits before mentioned.

THIN PLATES.

Depths.	1 in. to 3 in.		3 in. to 6 in.			Mean of all depths.	
	Value of c.	Coeff.	Value of c.	Coeff.		Value of c.	Coeff.
Notch 3 ft. long.	5·10	·660	4·68	·606		4·89	·633
,, 10 ft. ,,	5·76	·746	[illegible]·16	·668		5·46	·707
Mean of all lengths.	5·43	·703	4·92	·637		5·17	·670

PLANK WEIRS, 2 IN. THICK.

Depths.	1 in. to 3 in.		3 in. to 6 in.		6 in. to 9 in.		Mean of all depths.	
	Value of c.	Coeff.	Value of c.	Coeff.	Value of c.	Coeff.	Value of c.	Coeff.
Notch 3 ft. long.	3·96	·512	4·44	·575	4·62	·598	4·34	·562
,, 6 ft. ,,	4·14	·536	4·62	·598	4·44	·575	4·40	·570
,, 10 ft. ,,	4·08	·528	4·56	·590	4 32	·559	4·32	·559
Mean of all lengths.	4·06	·525	4·54	·588	4·46	·577	4·35	·563

CREST 3 FT. WIDE, SLOPING 1 IN 18 ACROSS.

Depths.	1 in. to 4 in.		4 in. to 8 in.			Mean of all depths.	
	Value of c.	Coeff.	Value of c.	Coeff.		Value of c.	Coeff.
Weir 10 ft. long.	3·78	·489	4·08	·528		3·93	·508

CREST 3 FT. WIDE, LEVEL ACROSS.

Depths.	1 in. to 5 in.		5 in. to 8 in.		8 in. to 10 in.		Mean of all depths.	
	Value of c.	Coeff.	Value of c.	Coeff.	Value of c.	Coeff.	Value of c.	Coeff.
Weir 10 ft. long.	3·54	·459	3·78	·489	3·66	·474	3·66	·474

When an opening through which water issues is wholly below the surface of the pond, the velocity with which it issues is proportional to the square root of the head, that is, the height from the centre of the opening to the surface of the water, if the opening on the lower side be not covered with water; where water is discharged from one pond into another, through an opening wholly below the surface of the lowermost, the head is the height from the surface of one pond to that of the other. By the theory of falling bodies the velocity would be $8·02 \sqrt{h}$, h being the head of water in feet, and the velocity being measured in feet per second; but this velocity is never attained in practice; the opening is always more or less abrupt, and the whole body of water does not issue in a direction at right angles with the line of the opening, but, at the sides, is forced to converge towards a point outside, at

which point the cross sectional area of the body of the water is only about two-thirds of that of the opening. The velocity of the central portion of the body of water is probably as great as the theory indicates, but it is retarded at the sides by the friction against them, so that, besides the contraction of the area of the stream, the mean velocity of all its particles is also reduced below the theoretical velocity. Combining these two effects, the practical result is to reduce the discharge in the ratio of about 8 to 5.

In Banks's treatise on mills, a summary of coefficients found by numerous observers is given as follows :—

Newton, ·707 ; Bossut, ·615 ; Banks, ·750 ; Michelotti, ·625 ; Helsham, ·705 ; Smeaton, ·631 ; the mean of which is ·672, but it is to be remarked that the experiments of Bossut and of Michelotti were made on a larger scale than the others, and are more to be relied upon.

Experiments by Brindley and Smeaton, with holes 1 inch square, show the times in which 20 cubic feet of water ran out under different heads to be as follow :—

1	ft. head,	9	minutes	22	seconds.
2	,,	6	,,	40	,,
3	,,	5	,,	20	,,
4	,,	4	,,	44	,,
5	,,	4	,,	14	,,

From these we deduce the following coefficients, viz., ·64, ·63, ·64, ·63, and ·63 respectively.

In a report to the British Association, Mr. George

Rennie gave the results of the observations of others than those above named, as follow:—Venturi, ·640; Borda, ·646; Eytelwein, ·640; Hachette, ·690; Brindley and Smeaton, ·631; Rennie, ·621; Poncelet and Lesbros, ·600, ·605, and ·593; also from other experiments, ·611, ·618, and ·611. The mean of all these is ·625.

If there were no obstruction to the flow the quantity discharged in cubic feet per second would be $A \times 8\sqrt{h}$, A being the area of the opening in square feet, and h the head of water, but the combined influence of friction and reduction of cross sectional area of the stream causes a reduction in the constant to 5, in ordinary cases; so that the actual quantity discharged is $A \times 5\sqrt{h}$, through abrupt openings. With trained walls and other appliances the discharge would approach nearly to that indicated by the theory; Mr. Beardmore gives the constant 7·5 for such cases.

The word coefficient is used sometimes to express the quantity which I have called the constant, and perhaps there can be no liability to error in taking the word indiscriminately, although it would seem that the two quantities should be differently named. The *constant* is a quantity found by experiment to equilibrate two other quantities which are stated by the theory adopted; but a *coefficient* I take to be a decimal which shows the ratio between the theoretical and the practical quantities.

§ XVIII.—CONDUITS AND CONDUIT-PIPES.

IF the channel by which water is conveyed be an open cutting in the ground, the velocity of the stream must be small, as may be seen from what we have said (p. 75,) on the effects of scour on various materials, and therefore the dimensions of the channel must be proportionately large, and the fall proportionately small. A waterworks conduit, however, is usually lined with stone or brickwork, or with concrete, in order that a greater velocity may be given (the difference of level of the two ends usually permitting it), and the dimensions reduced. In this way a sufficient velocity is obtained to prevent the surface freezing, and to prevent the muddying of the water which would take place by running with considerable velocity over a natural bed. A mean velocity of from 2 ft. to $2\frac{1}{2}$ ft. per second is not an unusual one in practice. Eytelwein's equation, $v = \cdot 9 \sqrt{hf}$, is applicable to such a channel, in which $v =$ the mean velocity per second, $h =$ the hydraulic mean depth, $f =$ the fall of the conduit in 2 English miles.

Thus, with a hydraulic mean depth of 6 inches, and a fall of $6\frac{1}{4}$ ft. per mile, the mean velocity would be $2\frac{1}{4}$ ft. per second, for $h = \cdot 5$ and $f = 12\cdot 5$ and $v = \cdot 9 \sqrt{\cdot 5 \times 12\cdot 5} = 2\cdot 25$.

Such a channel might be so formed that the depth of water might be 1 ft., the width at the surface of the water $3\frac{1}{3}$ ft., and the width at the bottom $\frac{2}{3}$ ft. The

mean width would then be 2 ft., the sectional area 2 square ft., and the quantity of water conveyed 4½ cubic ft. per second, or 270 cubic ft. per minute. Larger channels, in which the hydraulic mean depth is greater, require proportionately less fall to maintain the same velocity; thus, if the hydraulic mean depth be 1 ft., and the velocity, as before, 2¼ ft. per second, the fall would be only half as much as in the other channel, for

$$f = \frac{v^2}{\cdot 81\,h} \quad \frac{5\cdot 06}{\cdot 81} = 6\cdot 25, \text{ or } 3\tfrac{1}{8} \text{ ft. per mile.}$$

Such a channel might have a width at the surface of the water of 6¾ ft., at the bottom of 1¼ ft., and a vertical depth of 2 ft. The mean width would then be 4 ft., the sectional area 8 square ft., and the quantity of water conveyed would be 18 cubic feet per second, or 1,080 cubic feet per minute. (The quantity in cubic feet per minute is converted into gallons per day by multiplying by 9,000.)

By that process the approximate quantity of water running in an existing channel may be found, but the more usual thing to be determined in a waterworks is the sectional area of the conduit from the known quantity of water required to be conveyed with a given velocity. In this case the first consideration is the rate of fall which circumstances permit, so as to deliver the water at a sufficient elevation above the place to be supplied. The highest part of the district to be supplied determines at what elevation the service reservoir should be, and taking that as a datum the rate of fall in the several parts of the line of conduit up to the source may be accommodated to the requirements of

the several parts of the ground. In some parts a conduit following the contour of the ground may be most economically made, while in other parts it may be necessary to confine the water in pipes under pressure, and in some places a short valley or ravine may be crossed by an aqueduct.

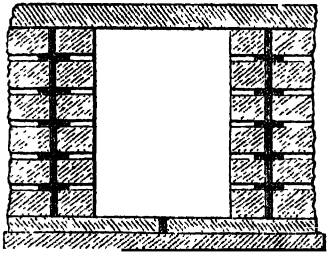
Open channels in the ground, however, which convey water for domestic use, require to be fenced in, and the expense of that is in some cases greater than the expense of covering the conduit, when it is of small dimensions. Covered conduits are mostly of one or the other of two forms: either completely circular, or with vertical sides and arched cover, the bottom in this case being usually formed with an inverted arch from side to side, unless flagstones are used. The choice of one or the other form depends chiefly on the local materials used. The quantity of material required is less in the circular form, but in this case the beds of the stones should be dressed or the bricks moulded to the radius of the curve, in order to make good work; and the labour of this costs more than the extra materials in the other form, where they are abundant.

To prevent leakage the conduit is sometimes laid i puddled clay, from 8 to 12 in. thick, worked with littl water, up to the middle of the height of the conduit or higher; and to prevent the percolation of wate from the surface, in places where it might be injurious, the puddling is completed over the arch.

Instead of being backed with puddle the beds and joints of the heart of the walls may be filled with asphalte, hydraulic lime mortar being used for the

inner and outer parts of the beds and joints, as in the following Figure.

Fig. 32.



It is essential to the purity and freshness of the water delivered at the lower end of any conduit that during its passage it should take up oxygen from the atmosphere as fast as it gives out that which had been previously absorbed, and to this end an open channel is preferable to a covered one, but where it is necessary to cover the conduit full provision should be made for its ventilation. The number of openings forming communication between the interior of the conduit and the atmosphere cannot be too many. The proper number will depend upon the degree of freedom from organic matter of which the water may originally be, but 100 yards would seem to be as far apart as the ventilating shafts should be in any case; and these, while having each a large area, should be protected by a hood from the possibility of pollution.

The quantity of water conveyed by either form depends upon the same conditions which affect the flow of water in open channels, and the conduit must always run somewhat short of full; half-full is the usual maximum state. Such conduits must therefore necessa-

rily follow the contour of the ground for the most part, although when a ravine or short valley has to be crossed that is easily done, without breaking the continuity of the gradient, by supporting the aqueduct upon piers brought up from the ground below.

To convey water under pressure from a high source along low ground, the principles to be regarded are in some respects different from those we have considered. The free oxygen originally contained in the water cannot escape, or should not be allowed to do so if at all possible. Cast-iron pipes are used for such conduits, and if the ground along the line chosen for the pipe do not in any intermediate part rise and fall again, the air originally contained in the water will for the most part be retained until the water is delivered at the other end, but if circumstances make it necessary to lay the pipe over intermediate and subordinately high ground, the air will accumulate at these high intermediate points, and it then becomes necessary to provide for its escape, otherwise the pipe will become air-locked, and the flow of water retarded or wholly stopped, besides creating danger of bursting the pipe, from the concussion which the elasticity of the air allows the water to give to the pipe in the throbbing action caused by the repeated efforts of the column to pass the obstruction; and these efforts are cumulative; so that in all such cases air-escapes are fixed on the pipe. When delivered into a sufficiently large reservoir it again in part takes up air.

Whether the pressure which causes water to travel hrough a pipe be that of a natural head of water at a igh level, or whether such pressure be artificially

given to it by a pump at a low level, is immaterial; the actual pressure must be the same in both cases; and in the case of a pumping main air-escapes at high intermediate points are still more necessary, for besides the risk of bursting the pipe without them, there is the risk of breaking the engine by the sudden relief of its load. But in pumping mains intermediate rises seldom occur. Where the ground does itself rise and fall again intermediately, the pipe is made to rise continuously by cutting through the hill.

Supposing air locks to be avoided, it is necessary to see that no unnecessary obstruction to the flow of water be offered by sharp bends. When none of these causes of obstruction exist, and the resistance to the flow of water is that due to the friction of the water on the sides of the pipe, the pressure necessary to give any required velocity may be calculated by Eytelwein's formula,-

$$v = 50 \sqrt{\frac{d\,h}{l + 50\,d}}$$

where v = the mean velocity in feet per second, d = the diameter of the pipe in feet, and h the head of water in feet necessary to give the velocity v: Squaring both sides of this equation, $v^2 = 2{,}500 \frac{d\,h}{l + 50\,d}$

and $h = \frac{v^2\, \overline{l + 50\,d}}{2{,}500\,d}$.

The correction $50\,d$ is made for short lengths of pipe, but in waterworks mains, such as those now under consideration, the correction may be neglected, and the equation is simply $v = 50 \sqrt{\frac{d\,h}{l}}$ and

$$h = \frac{v^2\, l}{2{,}500\,d}$$

As in the case of open channels, a good working velocity is from 2 ft. to 2½ ft. per second in conduit pipes also. It may be found by calculation that about 2¼ ft. per second is the most economical velocity through pumping mains, but for mains which convey water by gravitation the case is somewhat different, and in these, providing the source is sufficiently high above the point of delivery to give it, the velocity may be 3 ft. per second, or even more, economically, the size of the pipe being reduced accordingly.

It should be observed that it is the ultimate quantity to be conveyed which should be thus regarded. Presently necessary quantities of water are usually much exceeded to meet increased requirements, and this fact, derived from experience, should be duly regarded in determining the sizes of pipes and conduits.

If present velocity be made 1½ ft. per second it allows for a growth of upwards of 30 per cent. in the quantity of water before passing the assumed best velocity, and when the quantity shall have increased 50 per cent. more than the original quantity the velocity will be 2¼ ft. per second, which is about the limit of economical working; although twice as much water as may be supplied at first may be driven through the same pipe at a velocity of 3 ft. per second, when sufficient power is exerted to pump the water; but it is to be observed that the expenditure of power increases much more rapidly than in the ratio of the quantities of water pumped through the same pipe; it increases as the cube of the quantity, for, converting the power expended into the height which corresponds with the

pressure applied—that is, into the head of water—that height is proportional to the square of the velocity, and therefore to the square of the quantity through any pipe of given diameter, and in respect of the power expended in pumping the water to this head it is as the head and the quantity, or as the cube of the quantity; so that the power expended in pumping water through a pipe at the rate of 3 ft. per second is to that expended with a velocity of 2 ft. per second as 27 to 8, which is a ratio much greater than that between the cost of two pipes which shall deliver the same quantity of water in the same time at the rate of 2 ft. and 3 ft. per second respectively, for the cost of two such pipes would only be in the ratio of about 11 to 8.

From Eytelwein's equation already given, as translated by Dr. Thomas Young, and given in Tredgold's Tracts on Hydraulics, the diameter (d) may be found when the head (h), the length (l), and the velocity (v) are stated; or the head may be found when the other terms are stated; thus,

$$v = \sqrt{\frac{2{,}500\ d\ h}{l}}$$

$$v^2 = \frac{2{,}500\ d\ h}{l}$$

$$d = \frac{v^2\ l}{2{,}500\ h}$$

$$h = \frac{v^2\ l}{2{,}500\ d}$$

All dimensions being taken in feet, and the time per second.

Or we may find each of these directly from the

quantity of water, for the quantity is the product of the cross sectional area of the pipe multiplied into the velocity, whilst the area is the square of the diameter multiplied into ·7854.

If Q represent the quantity of water in cubic feet per second, and if l, h, and d be taken as before,

$$Q = \cdot 7854\, d^2 \times 50\sqrt{\frac{d\,h}{l}} = 39 \cdot 27\, d^2 \sqrt{\frac{d\,h}{l}}$$

$$= 39 \cdot 27 \sqrt{\frac{d^5\,h}{l}}$$

$$d = \sqrt[5]{\left(\frac{Q}{39 \cdot 27}\right)^2 \times \frac{l}{h}}$$

$$h = \left(\frac{Q}{39 \cdot 27}\right)^2 \times \frac{l}{d^5}$$

If the quantity be taken in cubic feet per minute,

$$39 \cdot 27 \times 60 = 2{,}356, \text{ and}$$

$$d = \sqrt[5]{\left(\frac{Q}{2{,}356}\right)^2 \times \frac{l}{h}}$$

$$h = \left(\frac{Q}{2{,}356}\right)^2 \times \frac{l}{d^5}$$

Eytelwein's equation has been adopted in calculating Table No. 5 in Beardmore's Hydraulic Tables.

M. Prony, a French writer on hydraulics, as stated by Mr. Samuel Hughes in his treatise on water-works, derived from the same set of experiments which Eytelwein investigated, fifty-one in number, made by Du Buat, Bossut, and Couplet, the constant 48·49, instead of 50, as found by Eytelwein.

Perhaps the formula which gives results more nearly

agreeing with observed facts under most ordinary circumstances is Du Buat's.

Du Buat's formula, as given by Dr. John Robison, in his "Mechanical Philosophy," Art. *Waterworks*, is, in English measures,

$$V = \frac{307\ (\sqrt{d} - 0{\cdot}1)}{\sqrt{s}\ - L\sqrt{s + 1{\cdot}6}} - 0{\cdot}3\ (\sqrt{d} - 0{\cdot}1)$$

Wherein V = the mean velocity in inches per second.

d = the hydraulic mean depth in inches.

s = the slope or inclination of the surface of the current, and is the length divided by the fall. (Thus a fall of 3 ft. per mile is a slope of 1760.)

L = the hyperbolic logarithm of the quantity to which it is prefixed, and is had by multiplying the common logarithm of that quantity by the number 2·3026.

This formula is also applicable to pipes running full, and is very accurate for both pipes and open channels.

To facilitate its application in practice Dr. Robison has given an extensive table of the logarithms of the values of 307 $(\sqrt{d} - 0{\cdot}1)$, of the values of 0·3 $(\sqrt{d} - 0{\cdot}1)$ and the logarithms of the values of $\sqrt{s} - L\sqrt{s + 1{\cdot}6}$, of which the following tables are abridgements. The range of the hydraulic mean depth is from 1 in. (4 in. pipe) to 3 ft. (large open channel), and, of a slope, from 1 in 240 to 1 in 3,200.

TABLE I.

d	Log. of $307 (\sqrt{d}-0\cdot1)$	$0\cdot3 (\sqrt{d}-0\cdot1)$	d	Log of $307 (\sqrt{d}-0\cdot1)$	$0\cdot3 (\sqrt{d}-0\cdot1)$
1	2·44138	·27	8·5	2·93670	·84
1·2	2·48518	·3	9	2·94954	·87
1·3	2·50426	·31	9·5	2·96167	·89
1·5	2·53885	·34	10	2·97319	·92
1·7	2·56769	·36	11	2·99454	·97
1·8	2·58112	·37	12	3·01401	1·01
2	2·60580	·39	13	3·03189	1·05
2·2	2·62803	·41	14	3·04843	1·09
2·3	2·63839	·42	15	3·06383	1·13
2·5	2·65772	·45	16	3·07820	1·17
2·7	2·67556	·46	17	3·09170	1·21
2 8	2·68395	·47	18	3·10441	1·24
3	2·69989	·49	19	3·11644	1·28
3·2	2·71472	·51	20	3·12783	1·31
3·3	2·72181	·52	21	3·13867	1·34
3·5	2·73531	·53	22	3·14899	1·38
3 7	2·74805	·55	23	3·15885	1·41
3 8	2·75417	·56	24	3·16828	1·44
4	2·76589	·57	25	3·17734	1·47
4·2	2·77704	·59	26	3·18601	1·5
4·3	2·78240	·59	27	3·19438	1·53
4·5	2·79277	·6	28	3·20243	1·56
4·7	2·80269	·62	29	3·21020	1·58
4·8	2·80747	·63	30	3·21770	1·61
5	2·81674	·63	31	3·22495	1·64
5·5	2·83840	·67	32	3·23196	1·67
6	2·85812	·7	33	3·23877	1·69
6·5	2·87622	·73	34	3·24537	1·72
7	2·89296	·76	35	3·25176	1·74
7·5	2·90851	·79	36	3·25799	1·77
8·	2·92305	·82	37	3·26404	1·79

TABLE II.

s	Log. of $\sqrt{s}-L\sqrt{s+1\cdot6}$	s	Log. of $\sqrt{s}-L\sqrt{s+1\cdot6}$	s	Log. of $\sqrt{s}-L\sqrt{s+1\cdot6}$
240	1·10543	570	1·31597	900	1·42487
250	1·11553	580	1·32015	910	1·42746
260	1·12523	590	1·32426	920	1·43005
270	1·13453	600	1·32830	930	1·43263
280	1·14345	610	1·33226	940	·43515
290	1·15204	620	1·33614	950	1·43464
300	1·16035	630	1·33997	960	1·44011
310	1·16838	640	1·34373	970	1·41254
320	1·17612	650	1·34743	980	1·44498
330	1·18363	660	1·35108	990	1·44737
340	1·19092	670	1·35468	1000	1·44946
350	1·19803	680	1·35823	1100	1·47223
360	1·20490	690	1·36170	1200	1·49269
370	1·21158	700	1·36513	1300	1·51148
380	1·21806	710	1·36851	1400	1·52885
390	1·22435	720	1·37185	1500	1·54497
400	1·23048	730	1·37513	1600	1·56014
410	1·23647	740	1·37839	1700	1·57416
420	1·24232	750	1·38157	1800	1·58747
430	1·24805	760	1·38471	1900	1·60004
440	1·25360	770	1·38782	2000	1·61195
450	1·25903	780	1·39089	2100	1·62325
460	1·26433	790	1·39391	2200	1·63403
470	1·26951	800	1·39690	2300	1·64432
480	1·27461	810	1·39985	2400	1·65414
490	1·27957	820	1·40277	2500	1·66358
500	1·28445	830	1·40564	2600	1·67261
510	1·28923	840	1·40678	2700	1·68133
520	1·29391	850	1·41128	2800	1·68971
530	1·29851	860	1·41408	2900	1·69780
540	1·30300	870	1·41683	3000	1·70558
550	1·30740	880	1·41953	3100	1·71713
560	1·31172	890	1·42220	3200	1·72042

In the original tables the range of hydraulic mean depths is from $\frac{1}{10}$ inch to 100 inches, and of slopes from 1 in 1 to 1 in 24,000. The extreme numbers, however, seldom if ever occur in practice, and the numbers selected in the foregoing tables will be found to embrace most cases of practice in waterworks.

It will be useful to compare, by example, this formula with that of Eytelwein. It makes the velocity a little less than Eytelwein's rule, and is therefore preferable, as erring, if at all, on the safe side; while it makes some allowance for inequalities in the direction and inclinations of pipes and conduits.

Example.—Required the mean velocity of a stream, the hydraulic mean depth of which (d) is 1 ft., and its inclination (s) 1 in 1,800.

By Table 1, Log. of 307 ($\sqrt{d}-0{\cdot}1$	$= 3{\cdot}01401$
By Table 2, Log. of $\sqrt{s} - \mathrm{L}\sqrt{s}+1{\cdot}6$	$= 1{\cdot}58747$
There remains . .	$1{\cdot}42654$
which is the log. of	$26{\cdot}70$
From which take, by Table 1, the value of $0{\cdot}3\ (\sqrt{d} - 0{\cdot}1) =$ . .	$1{\cdot}01$
There remains . .	$25{\cdot}69$ inches

$=2{\cdot}14$ ft. velocity per second.

According to Eytelwein's rule the hydraulic mean depth (h) $= 1$; the fall in two miles $(f) = \frac{5280 \times 2}{1,800} = 5{\cdot}87$; and the mean velocity per second $(v) = {\cdot}9\sqrt{hf} = {\cdot}9\ \sqrt{1 \times 5{\cdot}87} = 2{\cdot}18$ ft.

Example.—Required the mean velocity through a 12 in. pipe, the fall of which is 1 in 530.

The hydraulic mean depth in the case of a circular

pipe is always $\frac{1}{4}$ of the diameter, and is in this case, therefore, 3 in.

By Table 1, Log. of $307(\sqrt{d}-0{\cdot}1) = 2{\cdot}69989$
By Table 2, Log. of $\sqrt{s}-L\sqrt{s+1{\cdot}6} = \overline{1}{\cdot}29851$

There remains . . . $\overline{1{\cdot}40138}$,

which is the log. of . . . . 25·20

From which take, by Table 1, the value of $0.3(\sqrt{d}-0{\cdot}1) =$ . . 0·49

There remains . . $\overline{24{\cdot}71}$ inches

=2·06 ft. velocity per second.

According to Eytelwein's rule the diameter $(d) = 1$; the head $(h) = 1$; the length $(l) = 530$; and the mean velocity per second $(v) = 50\sqrt{\frac{d\,h}{l}}$. Squaring both sides of the equation, $v^2 = \frac{2{,}500\,d\,h}{l} = \frac{2{,}500}{530} = 4{\cdot}717$, the square root of which is 2·17 ft., the velocity per second.

But if, as Eytelwein directs, we add the correction 50 d to the length, then $\frac{2500}{580} = 4{\cdot}31$, the square root of which is 2·08 nearly, and this agrees very nearly with the velocity found by Du Buat's formula.

The following are the parts of the Act relating to water-works to which we point attention. Under sec. 54, a local authority has the same powers for laying water-pipes as for laying sewers, which we have already described, both within the district and beyond it.

By sec. 61, any local authority may supply water to the local authority of an adjoining district, and this is of much importance, for in some rural sanitary districts

it is very difficult to find water of suitable quality and sufficient in quantity, while in an adjoining district there may be an abundance of good water more than the sanitary authority of that district require for their own population, present and prospective.

Some people think that the water procurable within any watershed area should be reserved for the use of the population of that area alone, but that must be allowed to be a view too strict for the occasion.

Section 62 is to the effect that where any house is without a proper supply of water the local authority shall give notice to the owner to obtain a proper supply, the occupier paying the water rate authorised by the local Act, if any, or where there is not any local Act in force, then at a cost not exceeding twopence a week; but the Local Government Board may order the rate to be more than twopence a week, *if the local authority apply to them*, and show that it is not sufficient in any particular case.

This question is one of practical difficulty for every local authority where water works are not established. Take, for instance, a village or small town where one-half or two-thirds of the houses have wells upon the premises which furnish a supply of water to those houses of an indifferently good quality for drinking and culinary purposes, and the rain-water tanks of those houses (after an expenditure similar to that before stated) furnish a certain quantity of water for washing and bathing purposes. Further, suppose these houses to have been built by or to be occupied by the pecuniously better sort of the people in those parts of the town or village where water could be had by sink-

ing these wells. Now the local authority have to meet this difficulty; they find the other half or third part of the houses upon ground which yields not even indifferently good water, but water which (if any at all be found by sinking a shallow well, such as could be paid for by a rate of twopence a week) is not fit to drink. How shall the local authority proceed? If they order that any given house be furnished with a proper supply of water, the owner will do his best to meet the order by sinking a well. If the water happen to be good, so; but if not, the local authority will have stultified their own position, and will have ordered to be done to-day what they must order to be undone to-morrow, for if the water is not good they must put in force the 70th section of the Act.

I have thought it well to give this view of the case, because the difficulty often arises and has caused disputes in local councils as to the interpretation of the 62nd section, but it is evident that that section does not apply to such a case, but that it contemplates that a general water supply is at the command of the local authority, and that any house may be ordered to be supplied from that general source if the charge will not exceed twopence a week, &c.

Even if good water could be procured from a shallow well sunk on the premises of the house to be supplied, the cost would in general be more than twopence a week would cover.

Any usual water rate is one which covers all costs and charges of making and maintaining the works, and the current expenses of the supply; and the twopence a week, or 8*s*. 8*d*. per annum, must be considered as like-

wise covering all such costs, charges, and expenses of the supply; and a fair rate of interest on the outlay would be 6¼ per cent., to cover the interest and charges upon the money expended. The money to be expended, therefore, must not exceed about £6 13*s*., or say £7, in order that twopence a week may be an adequate charge for the water supply.

A well would in most cases cost more than that.

GLOSSARY OF TERMS.

Asphalte.—There is found in Val de Travers and other parts a limestone which contains asphaltum or native bitumen, and this, reduced to powder and otherwise treated, is the true asphalte. That which is described in the book may be called home-made asphalte.

Boulders.—Detached pieces of the older rocks, rounded, as we find them and the smaller pebbles on the sea shore. They are mostly very hard, and make good road material; those, at least, which appear to have been derived from the trap-rocks.

Concrete.—Broken stone or burnt clay, or gravel, mixed with any cementing substance, as lime or Portland cement. It is necessary that the material to be cemented together be free from dirt, for the strength of the concrete depends upon the cohesion of the materials, and unless the surfaces of each separate piece of material be clean, the cementing substance will not adhere strongly to them. For various purposes various quantities of cementing substance are required to be mixed with given quantities of material, but for any purpose referred to in this book one part of cement or of hydraulic lime to seven parts of material is sufficient, if well mixed. Concrete should never be mixed on the bare ground, but upon a platform. The material being spread out, and the due proportion of lime or cement spread out upon it, water is to be sprinkled over them from the rose-head of a watering-can, and the whole is then to be turned over and returned, again and again, so as to coat every separate piece of material with the cementing substance, and the concrete is then to be deposited in place and trimmed level. That is all that is necessary when the concrete has been well mixed. Wheeling it to a stage for the purpose of letting it fall from a height in order to consolidate it is useless labour; so is ramming, unless it be

done at the moment which occurs between the adherence of the cement and its setting; at any other time than this ramming does more harm than good. No sand or other substance than the lime or cement is to be mixed therewith, but the clean stones are to be allowed to come together, stone to stone, and to cohere by means of the cementing substance alone.

Coal-tar.—This is procurable at any gas-works. Owing to their remoteness from the chemical manufactories which distil and otherwise use coal-tar, or from other causes, coal-tar is to be bought very cheap at many gas-works; say at 2d. or 3d. per gallon. It is one of the waste products of the manufacture ot gas, which must be got rid of; but it has a value for the purposes mentioned in this book which is not to be measured by the necessities of demand and supply merely.

Cement.—Two kinds of cement are in common use,—Roman and Portland. Roman cement is made from the nodular stones found in clay at several places, as at the isle of Sheppy and at Harwich. It sets quickly. Portland cement is made from a mixture of chalk and clay, and when these are properly proportioned the cement sets under water as well as in the open air. If sand be mixed with cement at all it should be clean and sharp to the touch, but even with such sand the strength of the cement is reduced below that of neat cement, in about the same ratio as the quantities of cement and sand bear to each other; thus, with one of sand to one of cement, the strength ultimately becomes about two-thirds of that of neat cement. With 2 of sand to 1 of cement, about $\frac{1}{2}$; with 3 of sand to 1 of cement, about $\frac{1}{3}$; with 4 of sand to 1 of cement, about $\frac{1}{4}$ of the strength of neat cement. But the greater the proportion of sand the longer time is required for setting; with neat cement nearly the full ultimate strength is attained in about a month; with 2 of sand to 1 of cement, in about three months; while with a greater proportion of sand the setting goes on still more slowly. So that, for the work herein referred to, Portland cement should be used neat.

Hydraulic lime.—The best hydraulic lime is made from the blue lias beds of stone; these extend in a north-easterly direction from Lyme Regis, in Dorsetshire, by Bath, Gloucester, Leicester, Newark, and Gainsborough, to the Humber, and thence to the east coast of

Yorkshire at Whitby. Hydraulic lime is found also at Aberthaw in Glamorganshire, and at Halkin, in Flintshire. It sets under water as well as Portland cement. It is called a poor lime in contradistinction to others which are called rich or fat limes, as those which are made from chalkstone and the mountain limestone, which, although good for dry work, and for land, will not set under water. Its colour is a brownish yellow. It requires a much longer time to slake properly with water, and when slaked it swells but little in comparison with the fat limes. Instead of being slaked in lumps this kind of lime is ground into powder in revolving pans under heavy rollers, and used in the manner of cement. A part of the Wenlock Limestone is strongly hydraulic. It has very much the appearance of the blue lias, and burns of nearly the same colour,—rather darker. Neither this nor the blue lias will carry much sand.

Metalling.— As applied to roads, is the top coating of stone, or the road proper, and resists the wear and tear of horses' feet, being laid upon a bed of stone which is called the foundation of the road. The metalling of roads should be of such material as resists the wear of traffic, such as Whinstone, Rowley rag, and Clee Hill Dhu stone; this latter being one of the best kinds of stone in England for the metalling of roads.

Organic matter.—Matter endowed with life, whether animal or vegetable, or, as it would appear in some cases, partaking of the two; as distinct from mineral matter, which is devoid of life. Natural philosophers cannot exactly determine whether certain things which are found are animal or vegetable in their attributes, for they seem to partake of the qualities of both; but of living things in general, and broadly, there is a marked distinction in their qualities, and we call the one animal and the other vegetable; but both are organised,—that is, the parts of each are endowed with the quality of co-operating with its other parts in producing structure. When it has attained the limit of the power with which it has been endowed it decays naturally. If its life be cut short before it attains that limit it decays still. In either case, when its progress is arrested it returns to mother earth and is resolved into its original elements. This returning stage is called, in the book, effete organic matter.

Puddle, or puddled clay.—Clay rendered so close and compact as to prevent the passage of water through it. When clay is dug from the ground, it mostly contains either stones or small veins of sand, and it is to get rid of these that it is worked up, cut, and cross cut, with long-bladed spades, and trodden into an impervious mass. In order to enable this to be done a certain quantity of water is added to the clay. It greatly facilitates the working of puddle when time is allowed for the clay to soak up the water after being cut and cross cut, and before being finally worked and trodden.

Wall-plate.—The piece of timber laid upon the top of the wall to receive the feet of the rafters, or the tie beam, of the roof.

Wire gauge.—The Birmingham wire manufacturers established certain numbers which represent thicknesses, and specify any particular thickness not in parts of an inch but by the appropriate number. One eighth of an inch thick is No. 11 ; one sixteenth of an inch is No. 16 , one thirty-second part of an inch is No. 22 B. W. G. The thicknesses of sheet iron are stated in the same numbers.

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